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BAYER LEVERKUSEN (GERMANY)
Department for Plant Protection

Apple Powdery Mildew
Podosphaera leucotricha (Ell. and Ev.) Salm

by René Aerts and Dr. Albert Soenen
(Centre de Recherche de Gorsem)

Introduction

In an earlier paper published in 1952, we reported on observations and tests which we conducted during two years of research work (1951 and 1952) on this disease caused by *Podosphaera leucotricha* (Ell. and Ev.) Salm.

Powdery mildew has spread during recent years on such a large scale that it has caused orchardists much concern. Consequently we began to investigate this problem in 1951, and concentrated chiefly on developing a control method which would be both effective and economical.

During the first research year, we examined in field tests the value of the most important control methods suggested in recent literature. We ourselves were able to make a large number of observations concerning this fungus from the biological and epidemiological aspects. In the following year, we continued our research employing new methods which provided us with encouraging results. Following the discovery of certain new points, we finally changed our control tactics completely. The first paper was published towards the end of 1952, giving a summarized report of experience gained and the results obtained. We continued our work over the past two years with the aim of providing field workers with a satisfactory control method.

I. Biology of *Podosphaera leucotricha* (Ell. and Ev.) Salm

One of the order of *ascomycetes,* powdery mildew is a parasitic fungus belonging to the family of *Erysiphaceae.* In this fungus family, the fungus hyphae spread out on the surface of the plant host. Generally, the colour of the mycelium is white. The hyphae are hyaline, septate, and their threads are attached to the surface of the attacked organisms only by means of appressoria.

Continuing over a long period, the surface mycelium forms oval-shaped conidia of 28—33 µ × 10—15 µ which are arranged in the form of a chain at the end of the conidiophores. Once they have become separated, the conidia begin to germinate. As soon as the germ tube on the epidermis has reached a certain length, it sucks itself firmly into position by forming an appressorium. The hypha penetrates through an appendage at the end of which a haustorium develops.

According to Berwith (1936), the most favourable temperature for germination is between 19 and 22° C; the germination does not exceed 5 %. This

author is of the opinion that the infection between 13 and 25° C is completed in 45 to 48 hours. The conidiophores are said to be completely formed after an incubation period of 5 days.

Woodward (1927) conducted numerous germination tests, and arrived at completely different results. Occasionally there was no germination at all while in other cases germination was established but the figure obtained never exceeded 2 to 3 % (most favourable temperature: 10—15° C).

Powdery mildew reproduces in two ways:

a) by means of perithecia which overwinter on infested branches;
b) by means of mycelium quiescent in the buds.

Perithecia

Perithecia of *P. leucotricha* were observed and described by Ellis and Everhart (1888) in America long before they were discovered in our regions. Most authors refer to a relatively rare occurrence whereas more recent reports indicate that there has been an increase in the propagation of perithecia during the last few years. According to our experience of perithecia, they are spherical in shape, and their diameter varies between 77 and 110 μ. They contain only one ascus with a diameter of 55 μ. The thread-like appendages ermerging from the vertex of the perithecium are long and thin, whereas those at the base are short and often curved. On the average there are four of them, and sometimes only two. They are two to seven times as long as the diameter of the perithecia.

Perithecia are to be found relatively early in the year (June) on the shoots and on the main nerves of the leaf although they chiefly occur in very large numbers on rank shoots (we counted up to 1100 per cm).

With respect to abundance, we are able to assert from the observations made in 1951 that the perithecia occur in large numbers. 341 branch specimens were examined, and 96, in other words 28·1 %, were found to be carriers of perithecia. In addition, we examined 52 orchards and found perithecia in 67·3 % of them. We discovered the perithecia only on seriously infested branches. Generally, the opinion is held that the perithecia do not play any part in the spread of the disease and we have also arrived at the same conclusion. We caused certain perithecia to burst by employing a mechanical method. In several cases, 6—8 spores were visible in the ascus. The shape of the ascospores varied in every case, and it appears that they do not completely develop which may be the reason for the difference in shape. We tried unsuccessfully to cause the perithecia to burst artificially by placing pieces of bark covered with large numbers of perithecia in a drying chamber at a temperature of 20° C under moist conditions. The experiment which was started before the buds burst, was continued for two months but failed.

The mycelium

The other overwintering form of the disease, namely dormancy of the mycelium in the buds, is however, of very great importance. The buds containing the mycelium develop diseased shoots completely covered with mycelium and conidiophores. These shoots have a most characteristic mouldy appearance, and are an important source of new infections.

In Germany, Sorauer (1889) reported for the first time on the overwintering of the disease with the aid of mycelium. It was not until 1910 that

definite reference was made to overwintering inside the buds by means of the mycelium (Tubeuf). Final proof of this was first furnished several years later by numerous authors including Fisher, Baliard and Volck, van Poeteren, Holstermann.

We also investigated the presence of mycelium in the buds by making a pre-burst miscroscopic examination of buds which had developed on infested shoots from the preceding year. Sections of buds were prepared from Jonathan and Boskoop varieties. In both varieties, mycelium was found inside many of the buds. In addition, we carried out the following test which proves that the disease emanates from buds which are located on twigs that have been infected during the course of the preceding season. For this purpose branches were collected at a time when the buds were still closed. To accelerate the process of bud burst, the branches were placed in water and kept in a heating chamber at approx. 20 ° C. After they had burst, large numbers of the buds were found to contain conidiophores and conidia. In view of the state of the bud at this time, the possibility of an infection from outside can be eliminated. This experiment, therefore, indirectly supports the correctness of our microscopic observations. It should also be pointed out that the overwintering mycelium is concentrated at the tips of the inner bud scales.

II. Secondary Infections

A. Definition

In spring and in summer, *P. leucotricha* forms a conidiophorous mycelium. The conidium which has germinated on the leaf surface, develops 2 or 3 germ tubes. These penetrate through the cuticule by chemical means. The spots produced during conidial germination and the development of hyphae, are "secondary" symptoms of infection as opposed to those of the so-called "primary" infection. This completely covers the shoot which then assumes a characteristic mouldy appearance. It is to be attributed to the development of a bud which was infected in the year it was produced.

Secondary infections first appear in the form of white spots on the leaves. After a certain period of time, the leaves curl up in a most pronounced manner, with the result that zones of mycelium appear on the lower surface of the leaves, together with large numbers of conidia.

B. Significance

The question is raised as to how the disease is transmitted from the infected to the healthy organs.

In our opinion the perithecia have no part in this. It should be mentioned here that in the specialized papers which have been published, no precise data have been given on the germination and the powers of infection of ascospores. Many authors, however, believe it is most probable that this spore type is of certain significance for the spread of the disease.

Little importance was attached to the significance of secondary infections at the beginning of our observations. Woodward, regarded to be one of the greatest authorities on this disease, published a very detailed paper in 1927 entitled "Studies on *Podosphaera leucotricha* (Ell. and Ev.) Salm", in which he

expounded his views concerning the way powdery mildew spreads. Woodward believes that the axillary buds of the apple are infected in the earliest stage of their development. When the young shoots form in spring, axillary buds very soon develop in the axils of the young leaves. They are not completely surrounded by scales so that at their tip an opening is left for the infection to enter. This is effected by the hyphae of the mycelium which are present on the new shoot. In the case of all bud infections, the mycelium settles in the tissue very early in the season. Later, the scales form a compact protection and prevent penetration by fungi. The mycelium is completely viable in

Fig. 1 : Secondary infections on leaves

the bud all the year round, and remains there in a latent state until the next spring. Woodward assumes that the mycelium lies dormant in the bud for approximately 11 months. In fact this period of dormancy can continue for almost two years on rank shoots which develop on biennial wood. Woodward also determined the approximate percentage of buds infected on the branches by collecting shoots attacked in winter and placing them in water. On 40 to 50 % of these branches, the infection had also spread to the buds, and on the average he counted only one infected bud — there were seldom two or

more — per branch. In his opinion, the mildew on the bud shoot originates from mycelium which has remained dormant in the bud during the previous year, and not from an outside infection. The incidence of the disease in spring depends solely upon the presence of infected buds, and their number in turn determines the severity of the infection. The secondary infections originating from the conidia, only play a minor part in the spread of the disease. As proof of his thesis, W o o d w a r d describes the following experiment. Trees seriously infected by powdery mildew were transplanted in autumn. Easily identifiable, infested branches were carefully marked. In the following year despite favourable weather conditions, infections were established only on previously diseased shoots. Moreover, buds which contain no mycelium are able to remain healthy all through the summer even though they are located underneath infected buds on the same branch. This has been confirmed by observations continued over a period of two years.

From what we have observed, we can only say that there are certain points put forward in W o o d w a r d ' s thesis that are correct but others do not conform with the facts particularly in respect of the secondary infections which have a decisive influence on the spread of the disease. It should be mentioned that W o o d w a r d was just as much unable to find an explanation for the origin of the first bud infections as he was concerning the manner in which an infection is caused on organs not originating from infected buds. The observations we made outdoors (see below), prove that the secondary infections are chiefly responsible for the new primary infections of the buds. Primary infections are only possible as the result of secondary infections which in turn can only develop from sources of primary infection.

C. Process of infection

Two types of infection are encountered at all times of the year. A distinction has to be made between these:

1. An annual shoot is completely infected. In this case, it originates from a bud which developed secondary infection in the previous year. During the winter, the mycelium remained dormant in a latent state inside the bud, and continued its development after the bud burst.
2. The infection is restricted to certain organs, in particular to leaves. These develop colourless spots on their upper surface, which generally correspond to the mycelium sporulating on the lower surface.

We marked several hundred branches in 1951 and 1952. The re-check on these labelled branches was carried out every fortnight throughout the entire growing period (April to August) in 1952 and 1953. On the basis of the observations, the normal development of these two forms of infection can be conceived as follows.

1. Infection emanating from buds infected during the preceding year

A diseased bud has quite a different appearance from that of a healthy bud. Generally it can be recognized from its more slender and less compact form. The scales surrounding it are coarser, not so dense, and have a matt appearance (see Fig. 2).

Due to their special appearance, the diseased buds can be found in the middle of winter. We carried out the following test towards the end of winter 1952/53. We marked all axillary buds of abnormal appearance on two trees of the Jonathan variety, in order to check how many burst. When the check was made on April 22, 1953, it was found that 87 % of the marked buds showed symptoms of primary infection (completely covered with conidiophores and conidia) whereas the remaining 13 % had died without bursting. On both test

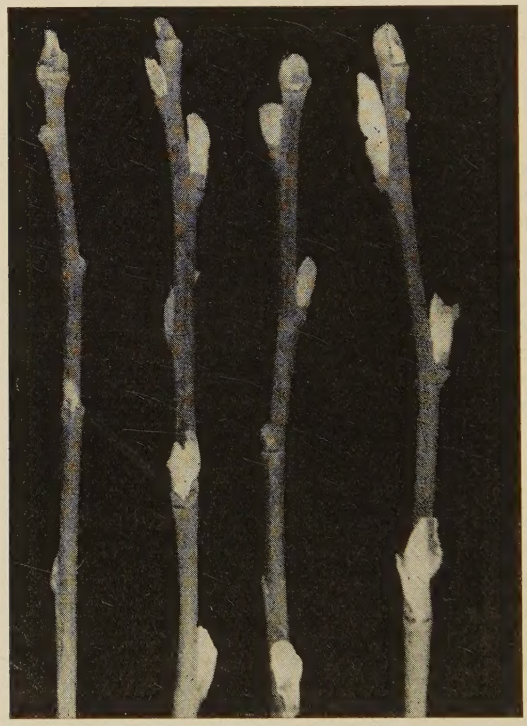

Fig. 2: Infested buds (left) compared with healthy terminal buds (right) (Photo taken before bud burst on Jonathan variety)

trees, all the other buds which were presumed to be healthy and which were not marked, developed in a perfectly normal manner.

A residue of mycelium was left at the base of the bud, on the original shoot, which indicates an infection caused the year before. At this point, the bark becomes whitish or grey in colour so that it stands out from the lower brown parts. Diseased buds always burst later than healthy ones. The first leaves hardly develop at all, and do not grow beyond the "apex" stage. The bud has no vigour (see Figs. 3 and 4).

The infected floral buds also develop much later.

On April 7, 1953 we examined the development stage of a number of infected floral buds. Whereas the healthy buds were already at the end of stage F (green bud), the buds infected by powdery mildew had hardly reached stage E (mouse ear stage). Moreover, they were about half the size of the healthy buds, and the short, narrow leaves were covered with numerous conidia.

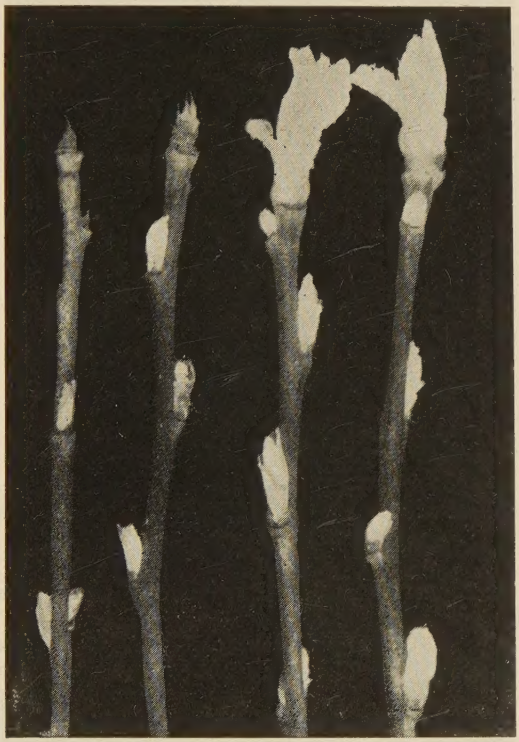

Fig. 3: Bursting of diseased (left) and healthy terminal buds (right) (Jonathan variety, April 1953)

On April 21, the difference was even more noticeable. The size of the diseased buds was 4 to 5 times smaller than that of the healthy buds. A large number had already begun to dry up. The "blossom" of these buds is particularly characteristic. The stalks are thickset, the floral leaves are fleshy, poorly developed and have a greenish appearance. All parts are covered with a flocculent layer of conidiophores and conidia. These "flowers" without a corolla do not open out, and they very rapidly become dry (see Fig. 5).

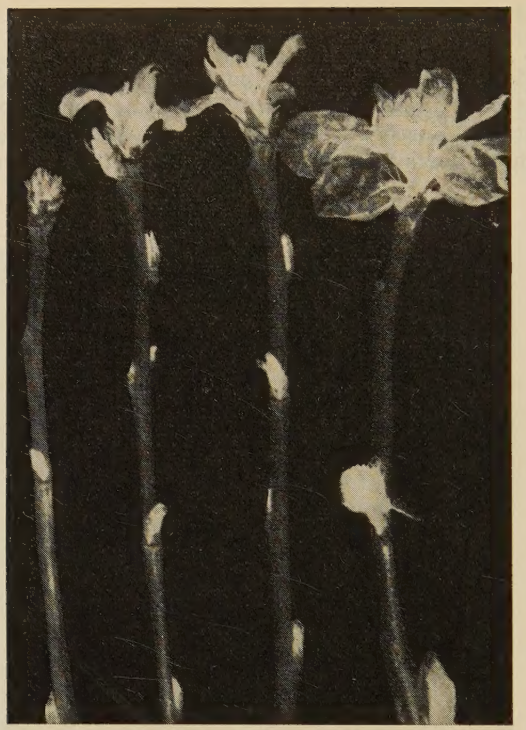

Fig. 4: Comparison between 3 diseased and one healthy floral bud (note the striking difference in size) (Jonathan variety, April 1953)

Very soon, conidiophores and conidia appear in large numbers on the growing shoots. At first they are visible at the base of the leaf stalk, and then they spread all over the leaf. The new parts become overgrown with fungus

Fig. 5: Left: Inflorescence infested by powdery mildew Right: Healthy inflorescence

during the course of their development, and assume a white, mouldy appearance. As a rule the shoot that emerges from a diseased bud, remains very short. It carries small leaves pointing more or less directly upwards, and which curl up in the form of a gutter. The leaves at the bottom part of the shoot soon become brittle, turn brown and fall off. From June onwards, most of the diseased branches begin to wither. The only leaves not seriously infested by necrosis on those branches which continue to develop, are the ones formed last. The condition of weakness which sets in at the base, gradually spreads upwards. Towards the middle of July, all the leaves of the diseased shoots have more

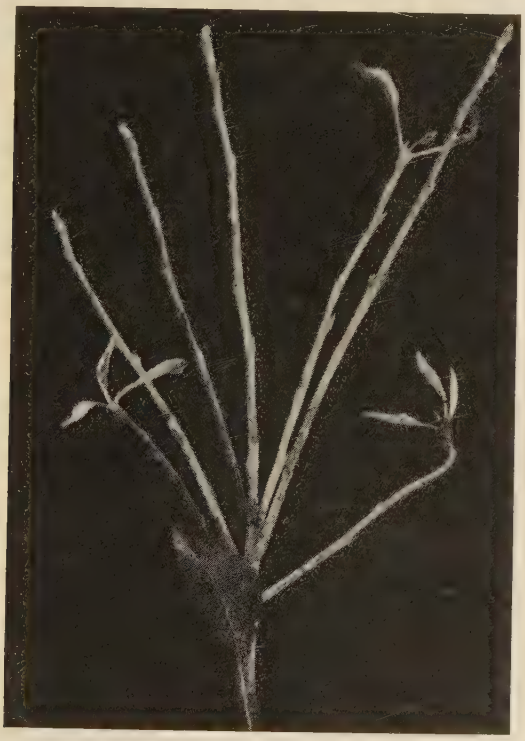

Fig. 6: Development in 1953 of a bud infected in 1952. Formation of a "broom-like shoot"

or less dried up, and finally only a small cluster of tiny leaves is left at the tips. In fact, on many branches there is not a single leaf to be found (see Fig. 6).

In the following year, very few axillary buds are formed on these leafless branches because most of the buds have been destroyed. Some do burst but mostly they are infected and die sooner or later, generally during July, without having formed any new shoots. In most cases, there is no longer a terminal bud on the branch. Exact counts have shown that there are between 20 and 42 % diseased and destroyed buds on such branches.

The opinion of Woodward is, therefore, correct when he says that the diseased terminal bud develops to form a shoot on which the axillary buds also become infected. It is also correct that these buds become infected early. We were able to convince ourselves of this fact by carrying out the following test. In 1951, 200 infected branches were sprayed regularly every fortnight from June 1 to August 15. The spraying schedule was drawn up so as to make allowance for the residual effect of each preceding treatment, and to ensure that the growing shoots were constantly covered with spray wash. Sprays of wettable sulphur were applied on the following dates: June 1, June 15, July 1, July 15, August 1 and August 15.

It was found in the check carried out in spring 1952 that the percentage of infected axillary buds on the treated shoots was not less than on the non-sprayed shoots. This suggests that the infection of the axillary buds on the diseased shoot begins very early in the year, in fact as soon as they are formed. It appears that this occurs chiefly during the period of vigorous growth in May.

The axillary bud infections, however, can by no means provide an explanation, as Woodward believes, for the progressive infection of the tree. It has been established that these buds die early before a shoot is formed. They can only contribute to the spread of the disease insofar as they bring forth conidia which cause secondary infections on healthy parts. Our experience has shown that they only produce conidia on a restricted scale, and merely constitute insignificant sources of infection.

2. Infections by conidia

The most important sources of infection are surely those diseased shoots on which huge numbers of conidiophores and conidia are produced, particularly during the months of May and June. Afterwards the formation of conidia is a much slower process. This fact may probably be attributed to a necrosis of the leaves, which also affects the mycelium.

During the course of the past four years, we observed the first conidia outdoors on the following dates:

1951: April 9	1953: April 1
1952: April 12	1954: April 16

There was not a single occasion all the time our observations lasted when we came across symptoms of secondary infections before the month of May. The first symptoms on leaves were discovered on the following dates:

1951: end of May	1953: May 11
1952: May 12	1954: May 17

At the beginning, these symptoms are visible on the young leaves in the form of yellowish spots which either remain unchanged or spread out. In the latter instance, the infested leaves crinkle most considerably, particularly those on the top part of the shoot, and assume an upright position. Their lower surface is covered with whitish, strongly sporulating zones of mycelium. Under the influence of light, these zones finally change to a violet colour, and the conidia disappear. The spots then remain localized, and appear to have healed (this effect is mostly to be seen during the month of June). On the other hand, other infested parts begin to spread along the main veins as far as the leaf stalk. From here, the mycelium extends all over the branch itself, both in an upward as well as in a downward direction, although propagation

is chiefly upwards. Numerous observations made of branches during the course of three years have shown that the migration of the fungus from the leaf to the branch always takes place in June (insofar as it involves the early infections).

In 1952 and 1953, the first zones of mycelium on the branches were discovered during the first days of June,
and in 1954 on June 20, some time later.

Fig. 7: Development in 1953 of a branch seriously attacked by secondary infection originating from 1952. Note the zone of mycelium on the top section of the branch, and the retarded growth

Therefore, approximately one month elapses from the time the first symptoms are detected until the shoot is covered with fungus. The aim of the mycelium, therefore, is to reach the tip of the branch as early as possible, and to cover the terminal bud. This bud is then either completely destroyed or infected during the following year. The branch which emerges in the next season from the infected bud then develops in a manner similar to that described above.

Before we discuss in detail the question of conditions governing an infection, we have given below a list of the periods in three successive years when infections occurred in the Limburg district:

1952:

a) from May 1 to 3
b) from May 15 to 19
c) the last six days of June
d) from July 20—27

1953:

a) from May 1 to 3
b) from May 16 to 26
c) between June 7 and 14
d) end of June
e) from August 12 to 21

1954:

a) from May 9 to 14
b) from May 25 to 28
c) from June 15 to 24
d) from August 1 to 6

Fig. 8: Development in 1953 of a branch also attacked by secondary infection originating from 1952. The mycelium has covered the extreme end of the branch, and has destroyed the terminal bud and a section of the shoot

A strange fact about this is that two infections occur in May of each year. We shall see from the data given in the following chapter that these infections are also the most serious. Our observations revealed that the incubation period (the time which elapses between the infection and the appearance of spots) lasts from 6 to 10 days. Once this period is over, the spots on the leaves are not only clearly visible, they also produce large numbers of conidiophores and conidia (Figs. 7 and 8).

III. Checks on Infections

A. Direct observations

We have seen in which periods secondary infections by powdery mildew took place during the last three years. In order to establish these facts, we changed over to direct observations in the field. Several hundred diseased and healthy shoots were selected from the Jonathan variety growing in our test plots. These shoots were carefully labelled in order to find them again without difficulty during the course of time, and to examine them thoroughly at regular intervals. The symptoms were noted on their appearance, and classified according to their degree of severity. The investigations were continued for two years so that the development of the branches and the progress of the infection could be followed.

1. Diseased shoots

In this test, we examined 250 infected shoots which were selected from our test plots towards the end of their development year, namely in 1951. The checks were carried out in 1952 and 1953 every fortnight from bud burst until the end of the growing period. The following points were noted in respect of each shoot at the beginning of the season (April):

a) Total number of buds;
b) Number and location of diseased buds on the shoot;
c) Number and location of dead buds on the shoot.

The checks indicated in the diagrams were carried out on the following dates in each case: April 20, May 15, May 30, June 20, July 15, 1952; April 15, May 15, June 15, July 15, August 15, 1953.

This applies to all the diagrams. Due to lack of space, we cannot repeat the corresponding data each time and give each separate count.

These data have been illustrated by means of sketches. The white circles represent healthy buds, the circles with a cross refer to diseased buds, and the black circles represent dead buds. These buds are depicted on both sides of a vertical axis which represents the carrying shoot. During the course of the test, as mentioned above, we also noted the secondary infections classified according to intensity. These infections are also entered in our sketches as follows: circles with a dot in the centre are weakly infected buds (merely spots on the leaves), double circles indicate moderate infections (large spots on leaves and curling together of certain leaves); serious secondary infections are represented by circles half blacked in (seriously infected leaves with a reduced surface, brown at the edges, and pronounced deformations).

It should also be mentioned that a bud developing into a shoot is illustrated in the form of a short line. On both sides of this line are small circles representing the different buds of the young branch. In order to show the ultimate stage of the infection, i. e. the appearance of the mycelium on the surface of the branches, we have marked the covered parts of the shoot with small black dots.

In order not to overburden ourselves unneccessarily with work, we have restricted our descriptions to the 15 most interesting cases. Each sketch includes 10 recordings (5 each year), each of which corresponds to the state of the shoot

at a definite time of the year. The number of recordings, therefore, was purposely kept to a minimum in order to stress the most characteristic stages of infection.

1st case: Development of a diseased shoot without terminal bud.

In Section C of the preceding chapter, we saw that in the majority of cases the terminal bud is missing on a biennial shoot which becomes infected in the course of the year. According to our counts, the terminal bud is destroyed in 65 % of the cases. Fig. 9 shows the development of a diseased shoot deprived of its terminal bud.

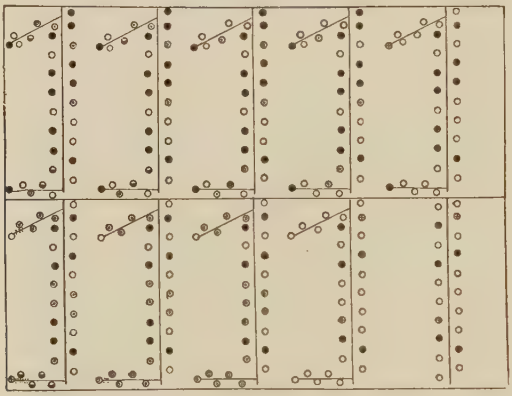

Fig. 9: Development of a diseased shoot deprived of its terminal bud — explanation given in text

1952

At the first check on April 20, 1952, the shoot bore exactly 20 buds (13 healthy, 2 diseased, 5 dead). On May 15, the first bud and the last bud but one developed into healthy branches.

The count on May 30 showed a moderate infection on the two young branches; a slight infection of the leaves of 5 buds; the last bud infected at the base of the shoot had died.

On June 20, it was found that the infection had spread to the upper branch (covering of mycelium); the infection had not affected the buds; the second bud infected (No. 7) had died.

On July 15, the following was observed: The mycelium covering had spread out on the upper branch; the appearance of the extremity of the branch indicated a probable infection of the terminal bud; mycelium had also appeared on the second branch; otherwise the situation had not changed.

1953

15. 4: The first branch was deprived of its terminal bud; the terminal bud of the second was dead.
Buds 11 and 12 had died.

15. 5.: Weak infections were observed on all parts (circles with dots in the centre); the terminal bud of the second branch had died; the 20th bud (base) was also dead.

15. 6.: Aggravation of certain infections; appearance of new infections.

15. 7. and 15. 8.: Aggravation of certain infections.

Fig. 9 illustrates the usual appearance of a diseased shoot; absence of the terminal bud; confusion of healthy, diseased and dead buds.

2nd case: Infected terminal bud which develops into a fruit bud.
The terminal bud is infected in 25 % of the cases.

Fig. 10 shows a shoot which has only 6 buds (note the size of the denuded space); apart from the terminal bud, they are all healthy at the beginning of the year. The state of the terminal bud did not change throughout 1952; on May 30 a slight infection was observed on one of the other buds but this did not spread; the other buds remained healthy, and 4, 5 and 6 developed very little.

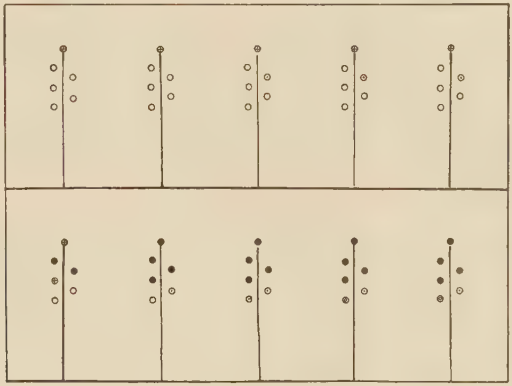

Fig. 10: Explanation given in text

In 1953, the terminal bud appeared as an infected floral bud. The 2nd and 3rd buds died, and the fourth also developed into an infected floral bud. The fifth was a floral bud, too, but healthy. The 6th bud also remained healthy.

At the second check, the terminal bud and the 4th bud had died; the fifth showed symptoms of slight infection whereas the sixth bud was still healthy.

At the time of the third check, only buds 5 and 6 were left; bud 6 showed signs of slight infection. The only subsequent development was an aggravation of the symptoms on bud 6. It should be mentioned that the flowering of the floral bud (No. 5) and the fructification proceeded normally; the fruit that developed, however, was somewhat reduced in size.

3rd case: The infested terminal bud does not develop into a shoot.

Our observations revealed that in 63·7 % of the cases, no shoots are formed from infected buds.

Fig. 11: Explanation given in text

It is evident from Fig. 11 that the growth at the end of the shoot is very scanty during two vegetation periods. It is reduced to a tiny rosette of withered leaves.

As in the preceding sketches, the incidence of secondary infections and their development may be preceived. Not a single bud produced a shoot. Buds which remained healthy in 1952 died in 1953.

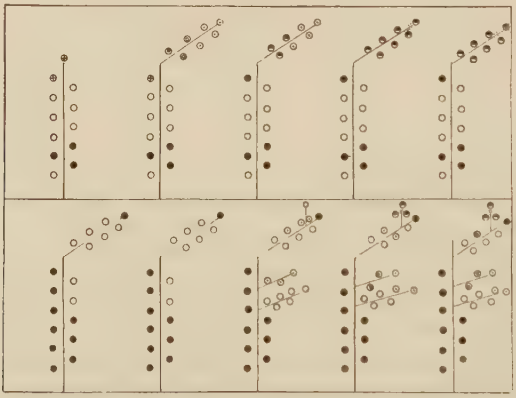

Fig. 12: Explanation given in text

4th case: Infested terminal bud develops into a shoot.

This development occurred in 37·3 % of the cases observed; the growth, however, rarely exceeds 15 cm.

Fig. 12 shows the development of a branch from the terminal bud (9 cm on May 15; 12 cm on May 30: growth terminated). Secondary infection rapidly

occurs, and spreads steadily. The mycelium appeared on June 20. In 1953, the terminal bud of this branch did not emerge; it was destroyed by infection. The branch bore 6 buds, of which the first developed into a shoot despite slight infection and finally grew to a length of 25 cm.

One notices the absence of infection on the other buds in 1952, yet only two buds developed into branches in spring 1953.

5th case: Healthy terminal bud which does not develop into a shoot.

Our experience has shown that the terminal bud of a diseased shoot remains healthy in only 13·4 % of the cases. It develops into a branch in only 44 % of the cases.

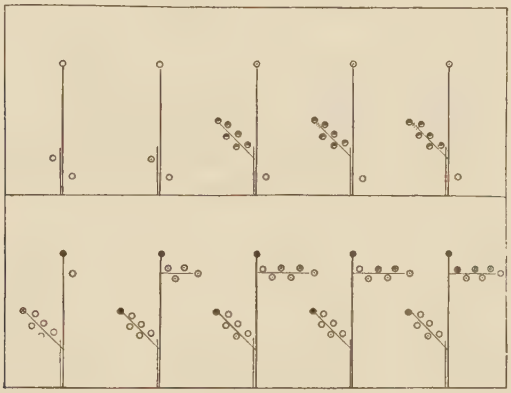

Fig. 13: Explanation given in text

A most typical case is illustrated in Fig. 13. The diseased shoot has only one terminal bud which develops into a leaf rosette with only slight symptoms of secondary infections. In spring 1953, the bud had dried but nevertheless another bud appeared immediately beneath it. This developed to form a branch which grew to a length of 15 cm by June 16.

6th case: Healthy terminal bud which developed into a shoot.

This is a most exceptional case. All the buds, including the terminal bud which burst on a diseased shoot in 1952 were healthy.

The development of this shoot is illustrated in Fig. 14. The terminal bud rapidly developed into a shoot which, towards the end of May, had grown to a length of 25 cm (termination of growth). It was attacked by secondary

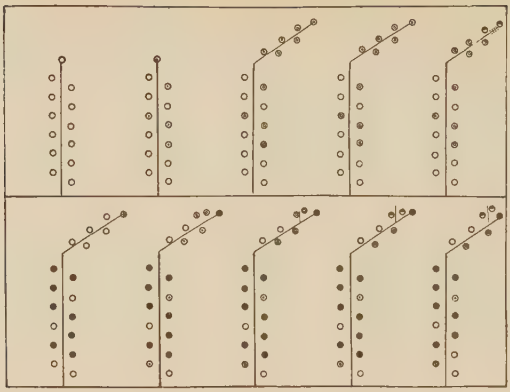

Fig. 14: Explanation given in text

infections, and the mycelium appeared in the middle of July. Its terminal bud was infested in spring 1953 and died in the middle of May.

From the bud burst in this particular year, it is again noticeable that most of the lateral buds are dead, in fact also those which did not suffer secondary infection.

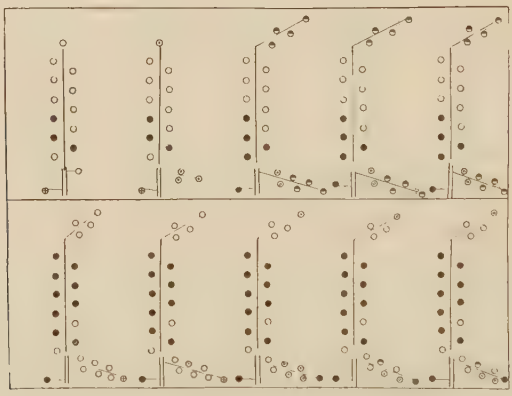

Fig. 15a: Explanation given in text

7th case: a) Healthy terminal bud which develops into a short shoot that remains healthy.

This case is typical for two reasons:

1. The terminal bud is healthy, and despite secondary infection it remains healthy also during the following year.

2. The lateral buds are not attacked by secondary infection; nevertheless practically all are dead in the following spring. Fig. 15 illustrates this process.

b) Healthy terminal bud which develops into a long shoot with its extremity destroyed.

This example provides a striking contrast to the previous one.

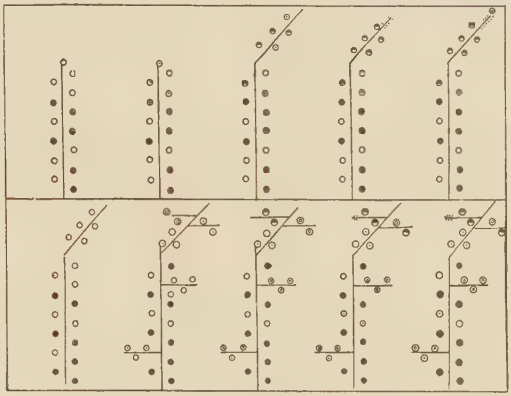

Fig. 15b: Explanation given in text

Fig. 15b illustrates what takes place in this particular case. The shoot which develops from this terminal bud is strong.

In the middle of July, it measures 35 cm but suffers from serious infections. In spring 1953, the last 2 cm of the shoot are dead but the first two of its 11 buds develop into strong shoots. It is also noticed that two lateral buds develop with strong branches (30 cm).

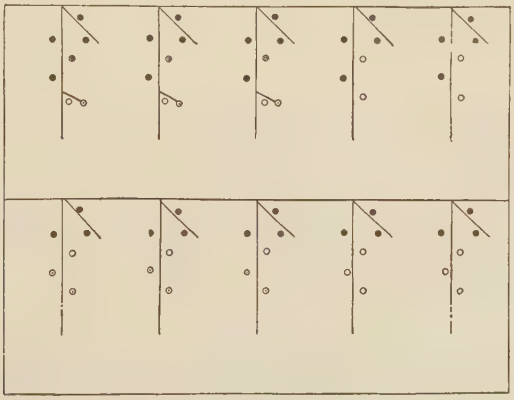

Fig. 16: Explanation given in text

8th case: Formation of a double shoot.

It often happens that an infected terminal bud develops into a double shoot. We encountered this phenomenon in 13 % of the cases we observed (33 times out of a total of 250).

The terminal buds may be missing on both shoots (Fig. 16); one may be missing and the other infected or healthy. It also happens that both terminal buds are present, and that both or only one is infected.

We have never discovered a case where both were healthy.

The sketch illustrates an example of a double shoot.

9th case: Recovery of an infected shoot.

This is a most exceptional case, and in fact we have never before come across one like it. It was observed on a double shoot. The terminal bud was missing on one of the shoots, while on the other the bud was infected.

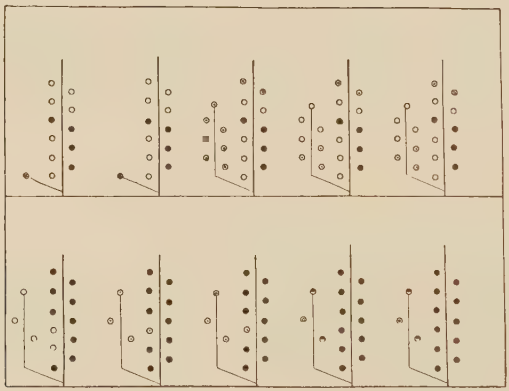

Fig. 17: Explanation given in text

It is evident from Fig. 17 that the appearance of the bud which originally was completely covered with conidia, began to improve (double circles indicate a less severe infection than the circles containing a cross). Following the bud's recovery, a shoot was formed which towards the end of the season had grown to a length of 25 cm. In 1953, the terminal bud of this shoot was healthy and in fact remained so until the end of the year although it showed slight symptoms which were attributed to secondary infections.

10th case: Concentration of infected buds at the base of the shoot.

This example is characteristic. The abundance of infected buds at the base of a diseased shoot is much greater than on other shoots, a fact proved by the following table.

Abundance of infected buds according to their position on a diseased shoot.

Total number of diseased shoots	Number of infected shoots on the lower third section of the branch	Number of infected shoots on the remainder of the branch
7	4	3
1	1	0
4	3	1
3	3	0
1	1	0
9	7	2
4	2	2
4	3	1
5	4	1
2	2	0
9	6	3
3	2	1
3	3	0
4	4	0
4	4	0
1	0	1
3	1	2
4	4	0
6	5	1
1	0	1
3	3	0
5	4	1
7	4	3
2	2	0
5	4	1
7	3	4
2	0	2
10	7	3
119	86	33

Fig. 18 illustrates a case where the proportion is 5 to 3. An important point to note is that all the buds infected on this shoot died early (end of May). In fact none of these buds developed into a shoot. This proves that apple powdery mildew cannot propagate this way as certain authors thought (Woodward, for example). He believed that the infection spread from year to year merely due to the uninterrupted development of the infected organs, i. e. a shoot is formed from a diseased bud, the axillary buds on this shoot become infected, diseased shoots develop from these buds, the axillary buds of these shoots become infected, too, and so on.

It is, of course, correct — as may be observed in nearly all the diagrams — that a diseased branch carries infected buds, and we have just seen that these buds are most abundant at the bases of the branches. It is also observed quite often that the lower part of the branch bears no buds. These denuded parts indicate that the buds which normally should have developed there, were destroyed by the disease. The way in which this occurs can be conceived as follows: A bud consists of a vegetative cone — CV — (meristematic tissue) and a certain number of primordial leaves and germs, or growing points of future leaves and axillary buds of the branch which develops from the bud. When this branch is infected it is highly probable that the primordial branches are infected, too. At the start of its growth, the branch is covered with a thick white, felt-like layer which consists of innumerable conidiophores and conidia. Consequently, the conditions are ideal for the infection of young axillary buds which are not yet closed. Later, the production of conidia becomes slower or

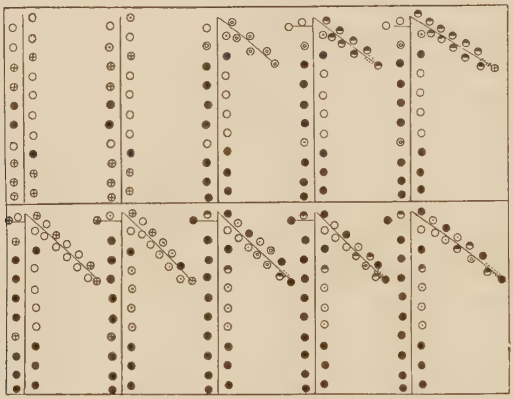

Fig. 18: Explanation given in text

it stops completely, whereas the branch continues to grow. Resultantly, the chances of an infection occurring on the new axillary buds which develop from the meristematic tissue, gradually diminish. Several are able to complete their development under the protection of a period of favourable weather conditions and acquire a protective layer of scales thus escaping the infection. This would explain the fact that on one shoot healthy and diseased buds are very often found together, as well as infected and destroyed buds on the lower part of a diseased branch.

11th case: Formation of a branch from an infected axillary bud.

We have included this case because of its exceptional rarity. In fact, it is the only one of its kind we encountered throughout the whole of our observations.

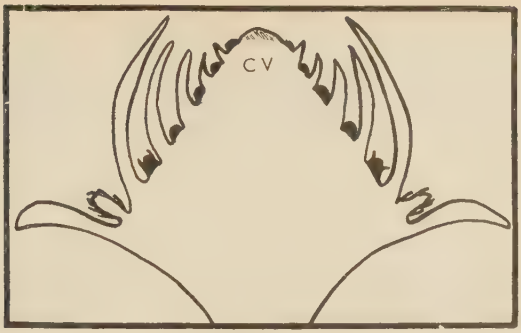

Fig. 19: Schematic illustration of a bud

Fig. 20 shows the development of a branch from the 3rd bud of the shoot. The branch had reached a length of 15 cm on May 30, 1952, but its growth had stopped by that time. On June 20, a mycelium zone formed on the upper part of the shoot and the tip was extremely withered. In spring 1953, the terminal bud was found to be actually infected, and it died at the beginning of June without having formed a shoot.

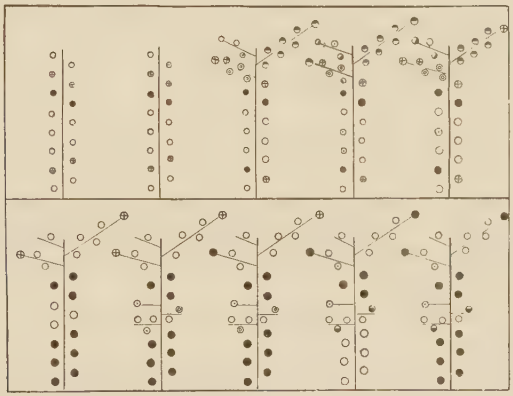

Fig. 20: Explanation given in text

12th case: Respective importance of the two periods of infection during May.

Fig. 21a: The second period of infection was the only one to occur here; all symptoms were noted in the 3rd check (May 30, 1952, and June 15, 1953).

Fig. 21b: (= Fig. 14): The only symptoms observed originated from the first period of infection (checks on May 15 in 1952 and 1953).

According to the results of all our observations, the percentages were as follows:

40 % of the infections were due only to the 1st period of infection,
18 % of the infections originated solely from the 2nd period of infection,
42 % of the infections are to be attributed simultaneously to both periods of infection.

2. Healthy shoots

The infected organs originating from the first two periods of infection very soon spread extensively. Check observations, therefore, had to be carried out on healthy shoots. The diagrams also reveal that most of the young plant parts were affected by the May infections. Such shoots could not be used for observing symptoms of possible subsequent infections. The cases described above

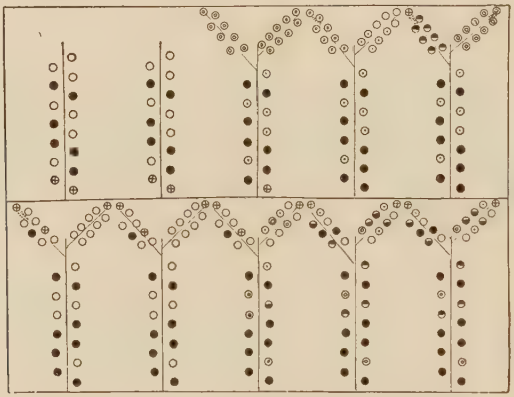

Fig. 21a: Explanation given in text

therefore refer solely to the occurrence and the development of symptoms originating from two early infections. The development of these was checked by regular investigations. The objects of the check on the healthy shoots was therefore:

a) to corroborate the observations made on diseased shoots;
b) to discover subsequent infections.

For this purpose, a certain number of healthy branches were marked each week, and they were checked leaf for leaf at short intervals (every 2 to 3 days).

A. 1952

In this section, we shall confine our remarks to a summary of the data recorded in respect of those branches which were under observation shortly prior to a period of infection.

1. Branches sampled for tests on May 15

On this date, the first symptoms of the year's secondary infections were already visible (since May 12).

The fifty branches sampled were completely spotless. The situation remained unchanged until May 25 when the first symptoms appeared. They multiplied and developed during the next few days. As proof of these facts, we have given below a brief tabulated summary of the development of the symptoms on ten of these branches as registered at 3 checks (seriously infected branches).

Branch	1st check 12. 6. 1952	2nd check 18. 7. 1952	3rd check 8. 8. 1952
I	Leaves at apex crinkled, numerous spots	Mycelium on branches (5 cm zone), no new spots	Mycelium on branches, tips wilted
II	3 leaves crinkled	Mycelium on branches, no new spots	Mycelium on branches, terminal bud active
III	Seriously infected leaves towards the apex	No mycelium, no new spots	Traces of mycelium on branch, apex wilted
IV	Leaves at apex crinkled	Terminal buds active, several new spots on 4th and 5th leaves	Terminal bud active, no mycelium on branch
V	Isolated spots on numerous leaves, no signs of crinkling	Terminal buds active, no new spots	Terminal bud still active, 2 new spots on leaf at apex
VI	Leaves at apex slightly crinkled	Terminal buds brown, no mycelium, no new spots	Terminal bud wilted, traces of mycelium on branch tip
VII	Old spots, 3 leaves at apex crinkled	No change, no new spots	Terminal buds wilted
VIII	Numerous spots and crinkled leaves	As on 12. 6., two new spots (isolated)	Zone of mycelium, terminal bud brown
IX	Apical leaves crinkled	Tip wilted, mycelium on extreme 2 cm, no new spots	As on 18. 7., terminal bud wilted
X	Apical leaves crinkled	Mycelium on last cm, no new spots	As on 18. 7., terminal bud wilted

Remarks:

1. Due to the strong infection, the growth of these branches ended in the middle of June.
2. No more than a few isolated spots were observed.
   The results of the infections were finally checked on May 1, 1953:
   a) The terminal buds were infected on branches III, VIII, IX and X (mycelium visible on these branches in 1952).

b) The terminal buds were destroyed on branches I, VI and VII (in 1952, mycelium on I, wilted terminal buds on VI and VII).

c) The terminal buds on branches II, IV and V were healthy (in 1952, mycelium not visible, and terminal bud active).

Conclusions:

1. Infections appeared between May 15 and 20 (confirmation of the data collected for diseased shoots).
2. The infections were serious: terminal bud infected or destroyed on more than half the examined shoots (29 in 50).

2. Branches sampled for tests on June 25

At the time they were sampled, these branches showed no symptoms of infection whatsoever. The first spots were discovered on July 4. The checks were carried out in the same way as in the preceding case.

Results:

25. 7.: Mycelium present on the branches in 40 % of the cases; spots on the leaves in 80 % of the cases; no symptoms in 11 % of the cases.

8. 8.: Situation unchanged; several new spots (new infections).

1. 5. 1953: Final check (50 branches): 7 terminal buds healthy; 31 terminal buds destroyed; 12 terminal buds infected.

Remarks:

The terminal bud is nearly always destroyed on branches with abundant mycelium. Generally, more destroyed or infected buds are to be found over the length of the infected zone (in one case where the mycelium extended over a length of approximately 10 cm, we found that the terminal bud was infected, also the 2nd, 4th and 6th buds; the 5th bud was destroyed).

Conclusions:

1. Infections occurred between June 24 and 30.
2. These infections were rather serious on the test shoots (branches in full growth in seriously infected test plots).

3. Branches sampled for tests on July 19, 1952

On this date, we sampled two batches of 50 shoots each, still in full growth:

1st batch: Healthy shoots (length of between 25 and 90 cm), showing no symptoms whatsoever.

2nd batch: Shoots already considerably infected (presence of mycelium zones on each shoot).

The checks were carried out as before:

1st batch:

30. 7.: Appearance of first spots.

8. 8.: Presence of spots on most shoots (apical leaves).

8. 9.: Aggravation of symptoms: leaves crinkled; presence of mycelium on 5 shoots.

2nd batch:

30. 7.: Terminal buds wilted on 38 shoots; terminal buds active on 12 shoots and apparently capable of surviving.

8. 8.: Situation unchanged plus new spots.

9. 9.: Extension of the mycelium zones to certain branches.

Final check carried out on May 1, 1953:

1st batch: 29 terminal buds infected;
21 terminal buds healthy.

2nd batch: 13 terminal buds infected;
37 terminal buds destroyed;
0 terminal buds healthy.
Numerous lateral buds destroyed.

Conclusions:

1. The infections occurred between July 20 and 27.
2. They were most considerable on the 1st batch (terminal buds infected in 58 % of all cases) but present on all branches.
3. The situation was disastrous on those shoots which were also infected beforehand (not a single terminal bud was spared).

B. 1953

1. May infections

The examination of the diseased shoots (see above) revealed that there were two successive periods of infection in May. This fact was confirmed by means of the method applied in 1952 using healthy shoots.

From the occurrence of the symptoms, it was established that:

a) the first infection took place between May 1 and 3;
b) the second infection took place between May 16 and 26.

2. Later infections

a) The infections were identified by means of the same method employed the previous year: Marking of healthy branches, and exact registration of discovered symptoms at short intervals.

b) The observations were confirmed by means of the following test: 4 batches of 50 branches were sampled for testing on June 8.

1st batch: Healthy branches (H) with no symptoms present.

2nd batch: Weakly infected (WI) branches with isolated symptoms (spots on leaves).

3rd batch: Moderately infected (MI) branches with more serious symptoms and curled leaves (2 to 4 per branch).

4th batch: Seriously infected (SI) branches with serious symptoms (numerous curled leaves: 5 to 10 per branch).

The length of the branches in each batch was also noted, and their growth was checked later.

Check on June 25:

Occurrence of new symptoms on most of the branches (infection from June 7 to 14).

Progressive elongated growth of all branches.

Appearance of mycelium zones on seriously infected branches (90 %).

Check on July 24:

Isolated cases of new symptoms on more than 50 % of the healthy and weakly infected branches (infection at the end of June).

Appearance of mycelium zones on the moderately infected shoots (50 %) and extension of these zones to the seriously infected shoots.

Presence of mycelium on several healthy (5 %) and weakly infected shoots (10 %).

From the end of June onwards, growth ceased on the majority of the seriously and moderately infected branches, also on approximately 50 % of the weakly infected branches, and on about 30 % on the healthy branches.

Fig. 22: Growth of healthy branches

Check on August 25:

Several new spots had appeared on healthy leaves (infections in August).

Situation unchanged concerning the extension of the mycelium zones.

Growth had ceased at the end of July on 90 % of the less seriously infected shoots and on 80 % of the healthy shoots.

Final check on May 1st, 1954:

	Healthy terminal buds in %	Infected terminal buds in %	Destroyed terminal buds in %
H branches	91	9	0
WI branches	85	7	8
MI branches	35	42	23
SI branches	0	34	66

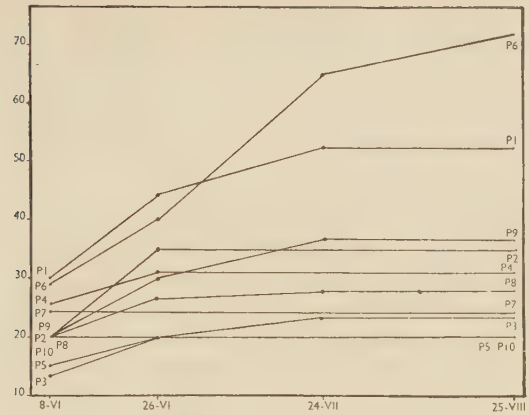

Fig. 23: Growth of weakly infected branches

It is evident from this table that:

1. The first infections were the worst (MI and SI branches).
2. The later infections inflicted further injuries amounting to 10 to 15 % (H and WI branches).

Graphs illustrating growth (see Figs. 22 to 25).

These curves which illustrate the development of growth of each of 10 branches of the above-mentioned batches, clearly show that:
a) secondary infections greatly reduce the intensity of growth;
b) secondary infections shorten the period of growth.

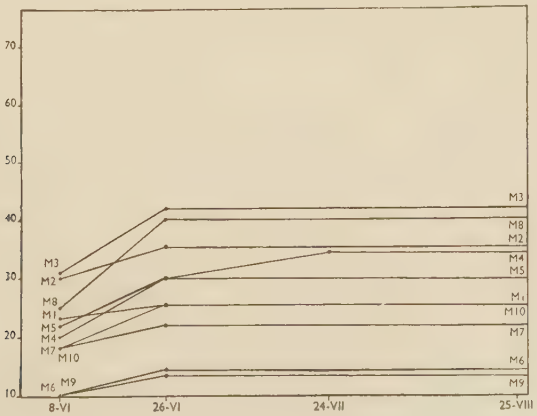

Fig. 24: Growth of moderately infected branches

The determination of the periods of infection was carried out by simply examining healthy branches. The method of observation employed was the same as that used in the preceding years.

Our remarks on these tests are limited to the results obtained:

1. There were two distinct periods of infection in May (from the 9th to the 14th and from 25th to the 28th).
2. There was one period of infection in June (from the 15th to the 24th).
3. There was one period of infection at the beginning of August (from the 1st to the 6th).

The most important infections occurred at the end of May while those in August were of a less serious nature. The other infections were only moderate.

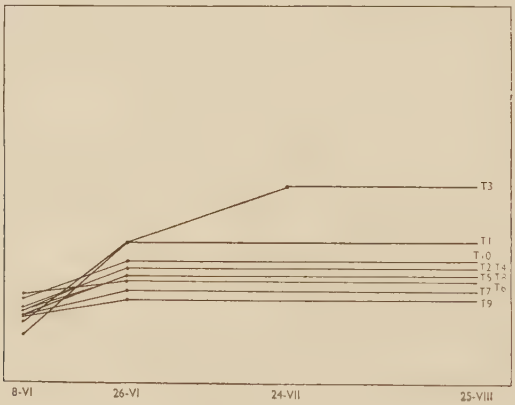

Fig. 25: Growth of seriously infected branches

B. Graphs on the presence of conidia

1. Methods

a) In order to gain an impression of the dissemination of conidia slides were repeatedly suspended in seriously infected tree tops, and then examined under the microscope. In 7 checks carried out in 1951 on April 18, April 25, May 5, May 10, May 15, May 23 and June 3, a certain number of conidia were counted each time. At the count taken on May 15, approximately 100 conidia were found on one slide.

Augmented counts were taken in 1952 and the values obtained were plotted on a graph in order to provide a picture of the strength and the development of the "conidia flights" during the season (cf. Fig. 26, dotted curve).

The curve continues to rise until May 16 when it reaches its peak. It remains at this level until the end of the month, and then gradually drops until well into July. In the second part of July, the curve suddenly rises

again and reaches a new peak by the end of the month. It then falls rapidly again and the "flights" cease about the 10th of August.

It should be mentioned that the peaks were reached during periods when there was little rainfall.

On comparing the results of our observations on the infections with the values given in the curve, it was found that the main periods of infection conform with the peaks of the curve in May and July.

b) These results encouraged us to pursue our observations in this direction. The slide method, however, was abandoned in favour of another procedure because it involved a considerable amount of time (suspension and removal of the slides) and rendered it necessary to carry out long microscopic examinations (examination of the entire surface of the slide even though often there was only a small number of conidia on it).

The following method was subsequently applied:

a) Firstly 5 leaf specimens of equal surface area (2 × 1 cm) were taken from marked trees, namely from branches known to have developed from infected buds.

b) Each specimen was immersed in 10 ccs of distilled water.

c) After being immersed, the specimens were centrifuged for two minutes to separate the conidia from the leaves.

d) After agitation, 3 drops of suspension were taken per specimen (a total of 15 drops).

e) Each drop was deposited on a concave slide.

f) The number of conidia was counted for two perpendicular diameters of each drop (objective used: 7 0·20 Wild microscope).

g) The mean calculated for 30 counts was plotted on the graph (checks every 2 to 3 days).

2. Course of curve

Curve 1953 (Fig. 26: broken line)

The first conidia occur on April 1st. The curve then rises evenly and reaches its peak on May 7 (first infection from May 1 to 3). It then falls gradually until the 16th, suddenly rises again, and reaches a new peak on May 19 (2nd period of infection from May 16 to 26). From this date onwards, the curve drops rapidly without interruption until June 3rd. It then rises to a new peak on June 8th (infection from June 7 to 14), followed by three more peaks of lesser importance on June 19, June 30 and July 7 (June infections). After attaining its peak of July 7, the curve drops rapidly and reaches zero on the 24th. It continues along a straight course until August 11, then rises again until it reaches its last peak on August 24 (August infections). It drops sharply at the beginning of September, and the flights cease completely towards the end of the month.

Curve 1954 (Fig. 26: solid line)

The first conidia appear on April 16, somewhat later than in 1953. With the exception of one stage from April 25 to May 8, the course of the curve is uniform, and it reaches its first peak on May 19 (infections from May 9 to 14). Following a drop from May 19 to 22, it reaches its main peak on May 25 (infections from the 16th to the 26th). Then the curve drops sharply and takes a

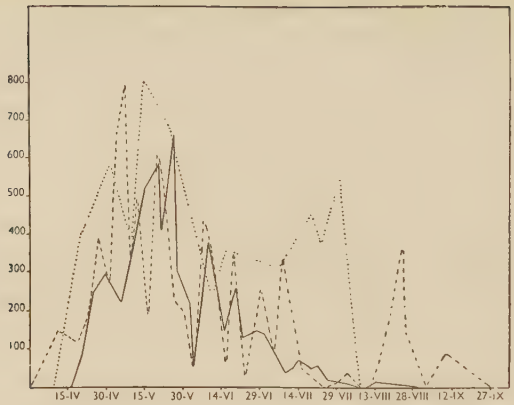

Fig. 26: Graph depicting the presence of conidia in infected tree tops
1952: dotted
1953: broken line
1954: solid line

very flat course until June 3. It then rises again to a new peak on June 9. From June 9 to August 5, the curve drops gradually in stages down to zero (secondary peak on June 20, infections from June 15 to 24). From August 5 to 13 (August infections), a slight increase in the flight activities was noticed but they ceased completely at the end of August.

3. Evaluation

These curves admittedly do not possess any absolute value with respect to the prediction of infections but they do offer valuable information:

1. The peaks generally coincide with the periods of infection occurring in nature.
2. No infections occur in the bases of the curves.
3. The highest points correspond to the most serious infections.

An abundance of conidia does not necessarily lead to infections. Other conditions must also be present, e. g. favourable temperature, no rainfall, calm weather, young organisms.

It is for this reason that the curve is not sufficient on its own to determine infections. Nevertheless, the following principle may be laid down: Every rise of the curve means a greater risk of infection. In fact, the conditions which cause an increase in the number of conidia (warm and dry weather) are also favourable for infections. Inversely, each drop of the curve indicates less danger of infections.

C. Artificial infections

1. Purpose

The artificial infection tests were carried out with the object of determining the conditions under which an infection caused by conidia can take place.

2. Method

All the tests were carried out in the following manner. Leaves infected by numerous conidia (at the beginning of the year, shoot tips infected by powdery mildew) were taken from untreated and seriously infected trees. The diseased organs were then brought into contact with the healthy leaves of young or old trees growing outdoors or in the greenhouse, and which belonged to varieties susceptible to powdery mildew (Jonathan, Reinette de France, Cox's Orange Pippin).

3. Tests

a) The first test series was conducted in April 1951. On April 20, the leaves on young branches of Jonathan and Boscoop varieties outdoors were coated with organs infected by powdery mildew (a total of 17 shoots). The weather was dry during the operation (r. h. 65 %), and the temperature was 15 ° C.

Results:

Several checks were carried out but we did not succeed in finding a single case of infection symptoms on the test branches. The leaves remained healthy throughout the whole of the season.

All the other tests conducted in 1951 produced negative results.

b) In 1952, 25 more tests were carried out in the field on trees of the Jonathan variety.

Only the two tests conducted on May 18 and July 27 produced positive results.

Test I (18. 5. 1952)

Weather conditions: temperature of 21 ° C, r. h. of 46 %, slightly cloudy, light wind blowing.

Results:

a) Occurrence of spots on three of the ten infected branches (from May 27 onwards).

b) No spots on old leaves.

Test II (27. 7. 1952)

Weather conditions: temperature of 23° C, r. h. of 67 %, cloudy, light wind blowing.

Results:

a) After ten days (5. 8.), spots on young leaves on two of five branches infected.

b) No spots on old leaves.

c) In 1954, a large number of tests were carried out in the field and in the greenhouse under the most varied of climatic conditions. In these tests, the temperature fluctuated between 10 and 30 ° C, and the relative humidity between 45 and 100 %.

Certain tests were conducted in dry weather, and others when it was raining. It would take up far too much space to give all the details of the tests, and therefore we have confined our report to the most important results.

A. Artificial Infections Outdoors

a) Tests at a temperature above 10 ° C: No result.
b) Tests at a temperature above 15 ° C: No result.
c) Tests at a temperature above 20 ° C: Out of a total of 30 tests, the following five were successful:

Temperature and relative humidity during the tests

Date (1953)	Temperature	Relative humidity
2. 5.	20·6 ° C	52 %
18. 5.	21·2 ° C	76 %
20. 5.	20·5 ° C	50 %
9. 6.	21·5 ° C	71 %
4. 7.	21·7 ° C	54 %

B. Artificial Infections in the Greenhouse

a) Tests conducted at temperatures between 10 and 15 ° C: No result.
b) Tests conducted at temperatures between 15 and 20 ° C: No result.
c) Tests conducted at temperatures between 20 and 25 ° C: 16 infections were produced out of a total of fifty tests. The successful tests were carried out on May 2 (3 tests), May 18 (2), May 22 (1), June 8 (2), June 9 (2), June 13 (1), June 22 (2), August 1 (1), August 4 (2).

Temperature and relative humidity during the tests

Date	Temperature	Relative humidity
2. 5.	24·0 ° C	49 %
18. 5.	26·3 ° C	70 %
22. 5.	27·1 ° C	68 %
8. 6.	20·2 ° C	90 %
9. 6.	24·4 ° C	75 %
13. 6.	20·0 ° C	88 %
22. 6.	23·5 ° C	89 %
1. 8.	21·6 ° C	65 %
4. 8.	25·7 ° C	56 %

C. Conclusions

1. The percentage of artificial infections successfully produced is lower in the field than in the greenhouse.
2. All the infections produced in the field occur during the periods of infection observed in the course of the year.
3. No infections are caused at temperatures of less than 20° C.
4. The infections lead to symptoms only on young organs. Old leaves appear to be resistant.
5. The infection can result at any relative humidity normally prevailing outdoors.

Remarks:

a) In the field, the spots occur only on the lower surface of the leaves, whereas in the greenhouse they appear on both sides.

b) In the greenhouse, the observations are frequently hindered by the presence of *Erysiphe polyphaga* Ham., a closely related fungus (similar symptoms and practically identical conidia: 28 μ × 15 μ).

IV. Conditions of Infection

In the preceding chapter, we have seen in which periods the infections occurred during the course of the past three years.

Taking into consideration the results of our observations on infection, the curves plotted for the flight of conidia and the results obtained from the artificial infection, the necessary conditions may be summarized as follows:

1. Presence of an adequate number of conidia.
2. Sufficiently high temperature, whereby the relative humidity is always sufficient.
3. Presence of young and turgescent organs.
4. No rainfall.
5. Very slight air movement.

Discussion of these conditions

Point 1:

While examining the curves plotted for the presence of conidia, we have seen that secondary infections always occurred when the curve ascended or when it continued its course at a relatively high level. Even the tests with artificial infection were chiefly successful when large numbers of conidia were present on the infection organs. It should not be forgotten that the percentage of germination is extremely low for conidia of *P. leucotricha* (3 to 5 % in the most favourable cases).

Points 2 and 4:

It appears as if a temperature minimum exists for the secondary infections No infections occur below 20° C. On the other hand, the relative humidity seems to be of no importance whereas rainfall has an unfavourable effect. (See following tables.)

A. Infections in 1952

Date	Max. temp. °C	Relative humidity 8 a. m. %	1 p. m. %	6 p. m. %	Weather
		a) from May 1 to 3			
1. 5.	25·4	55	36	31	mostly fine during the day
2. 5.	26·4	73	58	62	(rain at night),
3. 5.	21·4	87	87	74	slightly windy
		b) from May 15 to 19			
15. 5.	21·0	84	63	59	generally fine, no rain,
16. 5.	22·0	96	53	39	light wind
17. 5.	22·4	96	52	39	
18. 5.	21·2	68	47	45	
19. 5.	23·1	75	53	49	
		c) from June 24 to 30			
24. 6.	21·2	81	65	49	fine, no rain, light wind
25. 6.	20·3	60	64	68	
26. 6.	21·9	86	67	60	
27. 6.	19·6	75	44	43	
28. 6.	26·0	68	37	36	
29. 6.	28·7	56	34	34	
30. 6.	31·9	67	48	57	
		d) from July 20 to 27			
20. 7.	26·5	72	52	52	generally cloudy but no rain,
21. 7.	24·3	73	54	51	light wind generally
22. 7.	27·5	82	64	61	
23. 7.	20·6	82	79	54	
24. 7.	19·2	78	51	64	
25. 7.	22·2	98	73	68	
26. 7.	23·0	74	67	68	
27. 7.	23·8	66	68	82	

Date	Max. temp. °C	Relative humidity 8 a. m. %	1 p. m. %	6 p. m. %	Weather
		a) from May 1 to 3			
1. 5.	21·2	59	41	36	fine, no rain, light to
2. 5.	22·6	85	52	44	moderate winds
3. 5.	25·1	92	39	34	
		b) from May 16 to 26 (serious infections)			
16. 5.	22·4	64	35	45	fine particularly from 21st
17. 5.	28·7	89	47	40	to 25th, no rain, at first
18. 5.	23·0	74	76	70	moderate then light winds
19. 5.	22·8	74	48	60	
20. 5.	26·7	65	50	52	
21. 5.	23·3	85	69	63	
22. 5.	27·2	57	73	43	
23. 5.	25·9	75	59	54	
24. 5.	27·3	70	56	55	
25. 5.	29·2	75	46	38	
26. 5.	30·6	77	92	87	
		c) from June 7 to 14 (slight infections)			
7. 6.	20·4	100	91	93	moist especially at night,
8. 6.	18·7	87	71	92	light to moderate winds
9. 6.	21·9	100	100	100	
10. 6.	14·7	95	82	77	
11. 6.	19·7	80	62	65	
12. 6.	22·0	87	83	100	
13. 6.	20·1	83	75	90	
14. 6.	21·0	89	62	76	
		d) from June 28 to 30 (slight infections)			
28. 6.	22·1	83	61	59	fine weather between two
29. 6.	26·5	82	71	59	rainy periods, light wind
30. 6.	27·4	71	60	78	
		e) from August 12 to 21 (slight infections)			
12. 8.	24·7	76	44	46	rather fine, no rain except
13. 8.	31·5	67	64	59	on 18th, 20th and 21st,
14. 8.	27·9	82	55	58	light to moderate winds
15. 8.	26·9	77	68	67	
16. 8.	27·9	72	70	50	
17. 8.	22·6	62	53	59	
18. 8.	22·2	67	47	92	
19. 8.	24·7	84	59	58	
20. 8.	22·6	71	68	66	
21. 8.	23·1	90	92	72	

Date	Max. temp. °C	Relative humidity 8 a. m. %	1 p. m. %	6 p. m. %	Weather
		a) from May 9 to 14 (serious infections)			
9. 5.	25·6	65	46	42	fine and very dry,
10. 5.	27·7	60	39	34	light to moderate winds
11. 5.	28·1	68	34	81	
12. 5.	27·6	75	30	33	
13. 5.	25·5	51	29	28	
14. 5.	25·0	55	28	28	
		b) from May 25 to 28 (serious infections)			
25. 5.	25·8	54	32	35	warm and dry periods
26. 5.	28·7	54	33	31	between two periods of
27. 5.	29·8	56	27	31	rainfall, light wind
28. 5.	29·2	73	36	43	
		c) from June 15 to 24			
15. 6.	22·4	75	59	53	generally fine and no rain
16. 6.	21·0	75	64	67	except on 21st
17. 6.	21·5	80	69	71	
18. 6.	27·8	82	65	55	
19. 6.	30·8	78	50	48	
20. 6.	27·1	84	64	71	
21. 6.	22·8	85	80	58	
22. 6.	20·0	78	75	67	
23. 6.	22·2	81	63	77	
24. 6.	23·0	94	61	58	
		d) from August 1 to 6			
1. 8.	20·0	62	70	72	rather fine, rain at night
2. 8.	27·2	75	61	57	on 3rd and 5th,
3. 8.	31·0	77	43	53	moderate winds
4. 8.	28·5	64	58	64	
5. 8.	27·6	96	75	57	
6. 8.	22·9	84	69	68	

Conclusions:

1. These facts show that all periods of infection occurred when the maximum day temperatures were above 20° C, and in most cases it did not rain.
2. The high temperature alone is not sufficient. The weather must be dry (no rainfall), and at the same time there must be abundant numbers of conidia present.

Examples:

a) In 1952, the weather conditions were very favourable during the first half of July. Due to the heavy falls of rain during this period, the curve was very low.

b) In July 1953, the temperature was favourable practically all the time (26 maxima above 20° C) but due to heavy rainfall and low production of conidia, there were no infections.

c) In 1954 the conditions were the same (the temperature, however, was much less favourable).

3. Infections occur at any relative humidity. In fact they appear to be more serious in dry conditions. They do not occur when the leaf epidermis is wet.

Point 3

The symptoms of conidial infection appear only on young and sufficiently turgescent organs. This fact was repeatedly established during our observations and in our tests with artificial infections. Consequently leaves of a branch which has completed its growth early, are not affected by subsequent infections.

Point 5

Slight air movement is a favourable condition for the incidence of secondary infections. This fact was established in the greenhouse where it was easier to produce artificial infections than outdoors. Moreover, the spots develop both on the lower and on the upper surface of the leaf in the greenhouse. This seldom occurs in the field.

Stoll, the German author, arrived at a similar conclusion.

V. The Control of *Podosphaera leucotricha*

I. What is the situation regarding controls?

Numerous control methods are recommended for use against apple powdery mildew. On consulting the specialized literature on the subject, one is astounded at the number of preparations used, and especially at the varying recommendations concerning the times of treatment specified by the different authors.

The preparations listed include barium and ammonium polysulphides, lime-sulphur mixtures, colloidal sulphur, copper washes, Bordeaux mixture, wettable sulphur, combinations of lime-sulphur and iron sulphate etc. As a rule, preference is shown, however, for sulphur compounds.

Regarding the time of application, certain authors are of the opinion that spraying should be carried out as early as possible, in other words at bud burst. Some authors advise a succession of sprays before and after blossom based on the phenology of the host plant. Others, however, recommend either only a pre-blossom spray or only a post-blossom application. There are also certain authors who regard chemical controls as futile because they maintain that the mycelium cannot be controlled in the buds, and secondary infections are insignificant.

It should also be pointed out that most authors recommend the removal of infected branches as a measure complementary to the application of fungicidal sprays.

We have gradually formed our own opinion on this question of control during the course of our observations, and we propose to discuss the different phases on the following pages.

II. The first tests

1. Check on one particular method

When we began our research work in 1951, the control method generally employed consisted of iron sulphide wash (a combination of lime-sulphur mixture and iron sulphate) being sprayed in 2 to 3 pre-blossom applications and 5 post-blossom applications.

To check the efficacy of this method, the following test was conducted:

1. Selection of 11 test plots containing bush trees of the Jonathan variety seriously infested by powdery mildew.
2. Application of three sprayings using several preparations (see following list).

Tabulation of test data

Plot	Preparation	Dates of treatment 1st	2nd	3rd
I	B.S. + $FeSO_4$ + M	—	18. 4.	4. 5.
II	ditto	5. 4.	18. 4.	—
III	ditto	5. 4.	18. 4.	4. 5.
IV	B.S. + M	5. 4.	18. 4.	4. 5.
V	S.M.	5. 4.	18. 4.	4. 5.
VI	B.S. + $FeSO_4$ + M	5. 4.	18. 4.	4. 5.
VII	ditto	5. 4.	—	4. 5.
VIII	4255	5. 4.	18. 4.	4. 5.
IX	S. poudrage	5. 4.	18. 4.	4. 5.
Xa	B.S. + $FeSO_4$ + M	5. 4.	—	—
Xb	Check	—	—	—
XI	B.S.	5. 4.	18. 4.	4. 5.

B.S. = Lime-sulphur mixture
$FeSO_4$ = Iron sulphate
M = Wetting agent based on sulphonated alcohol (applied at 0.1 %)
S.M. = Wettable sulphur
S = Sulphur
S. poudrage = Sulphur powder

Dosage:

The sprays were applied at the following concentrations:

	1st	2nd	3rd
Lime-sulphur mixture	1·75 %	1·25 %	0·75 %
Iron sulphate	0·50 %	0·25 %	0·20 %
Wettable sulphur	1·00 %	0·75 %	0·75 %
4255-Urbacid	0·20 %	0·20 %	0·20 %

Results:

The infestation checks were carried out on May 19 by determining the percentage of infected shoot tips in a total of 300 per plot. The figures obtained varied between 35·4 % (Plot III) and 54·3 % (Plot IX). In the untreated check plot (Plot Xb), the rate of infection was found to be 48·2 %.

Conclusion:

The differences are too low to evaluate the efficacy of the methods and the preparations used. Moreover, the untreated check plot was not infected any more seriously than the treated plots.

The sprays were, therefore, ineffective. This test procedure was consequently abandoned, and it was decided not to apply any more post-blossom sprays.

2. The curative effect of the different products

We look upon this effect as including the destruction of the mycelium on the surface of completely infected shoots.

The number of conidia determinable microscopically on the leaves three days following the spray, was taken as the standard.

Four different tests were conducted in 1951. We propose to confine our remarks to a description of the most characteristic test, and to the conclusions drawn from the other tests.

Test conducted on June 1, 1951:

Method: Treated branches infected by powdery mildew (10 per preparation).

Variety: Jonathan.

Preparations and dosages:

1. Copper oxychloride at 0·2 %
2. Lime-sulphur mixture at 1 %
3. Barium polysulphide (with wetter)
4. Barium polysulphide (without wetter)
5. Organic sulphur at 0·75 % (normal spraying of shoots)
6. Organic sulphur at 0·75 % (thorough wetting of shoots)
7. Organic sulphur at 0·75 % (shoots immersed in the solution)
8. Preparation No. 4255 (Urbacid) at 0·5 %
9. Preparation No. 8186 (Ziram) at 0·5 %
10. Micro wettable sulphur at 0·5 %

11. Micro wettable suphur at 0·75 %
12. Micro wettable sulphur at 1·5 %
13. Preparation No. 4311 (carbamate mixture) at 0·5 %
14. Sulphur powder

N. B.: A wetter (0·1 %) was added to all the preparations.

Results for batches of 25 leaves (5 × 5); each figure represents a leaf average.

	Results on June 4					L.V.	Results on June 11					L.V.
Check plot	10	50	200	600	100	13	2 000	8 000	12 000	3 000	5 000	21
1	150	0	300	10	350	11	25	5 000	0	200	75	11
2	0	0	3	5	10	4	0	0	10	125	5	5
3	75	15	60	50	0	8	0	0	10	0	30	4
4	15	35	0	5	150	8	50	125	500	75	150	13
5	15	0	0	25	100	7	700	2 500	5	1 100	40	14
6	15	0	0	0	10	4	10	3 000	0	6	15	9
7	0	20	0	125	0	5	500	30	10	0	2	8
8	10	1	0	20	2	6	5	0	0	40	125	6
9	459	200	25	100	1 200	15	5 000	11 000	600	3 000	250	19
10	0	10	0	0	0	2	50	0	5	0	3	4
11	5	0	0	0	0	1	0	0	20	0	0	2
12	0	0	0	0	2	1	0	4	0	0	0	1
13	10	80	0	0	5	5	10	6	150	750	0	9
14	0	0	7	0	0	1	0	5	0	0	0	1

L.V. = logarithmic value
1 = 1 to 9 conidia
2 = 10 to 99 conidia
3 = 100 to 999 conidia
4 = 1000 to 10 000 conidia
5 = more than 10 000 conidia

Conclusion:

1. From the count taken on June 4, in other words, three days after the spray application, it is evident that only wettable sulphur and sulphur powder produced good results.

   When organic sulphur was used, there was no difference in efficacy for the various methods of treatment. Likewise, the different concentrations of wettable sulphur all produced a similar result.
2. The same conclusions can be drawn from the count on June 11 with the exception of wettable sulphur which gives a stronger effect at high concentrations.

Tests conducted on May 19, June 15 and May 10

These tests carried out in the same manner indicate the following:

1. All the substances tested produce a certain effect but wettable sulphur is the best preparation.

2. The effect of wettable sulphur may remain persistent for two weeks under the conditions of the test.
3. Micro sulphur produces the best effect among the different sulphur fractions used.
4. Heavy rainfall washes away a large part of the conidia (these reappeared, however, after 3 to 5 days).
5. The residual effect is more persistent in dry weather than in wet weather.

3. The curative effect of wettable sulphur

A. Test conducted in 1951

Methods:

Divisions of a Jonathan plantation into 11 plots.
Sprays applied at intervals of two weeks between June 1 and August 16.
Treatment of infected branches only (primary infections), using a hand sprayer.

Preparation: Micro wettable sulphur at a concentration of 0·75 %, with the addition of a wetter.

Spraying plan

Six sprays on Plots	1st 1. 6.	2nd 15. 6.	3rd 1. 7.	4th 15. 7.	5th 1. 8.	6th 15. 8.
			Sprays			
A	×	×	×	×	×	×
B		×	×	×	×	×
C			×	×	×	×
D				×	×	×
E					×	×
F						×
H	×					
I	×	×				
J	×	×	×			
K	×	×	×	×		
L	×	×	×	×	×	
Check plot				untreated		

Results:

1. 1951: The checks carried out on June 16 and August 21 produced the following results:
   a) The healthiest branches appear to be those in the plots sprayed five times.
   b) The first two and the last two sprays appear to have produced the greatest effect.

2. 1952: The check carried out in 1951 only gave a general impression of the state of the treated branches. In the following spring, a new check had to be carried out to establish whether there actually was an improvement. Therefore, the dead and infected buds were counted on all branches in the different plots.

The results are summarized in the following table:

Plots	Dead buds %	Infected buds %	Total %
A	30·9	3·4	34·3
B	21·9	9·0	30·9
C	23·6	6·3	29·9
D	14·6	4·9	19·5
E	25·1	12·6	37·7
F	22·4	4·7	27·1
H	25·3	12·0	37·3
I	38·6	2·8	41·4
J	18·6	17·2	35·8
K	21·1	13·1	34·2
L	28·0	7·1	35·1

These results are illustrated in Fig. 27 (the arrows indicate the treatments; the horizontal lines indicate the percentage of dead buds [solid lines] and the percentage of infected buds [broken lines], respectively).

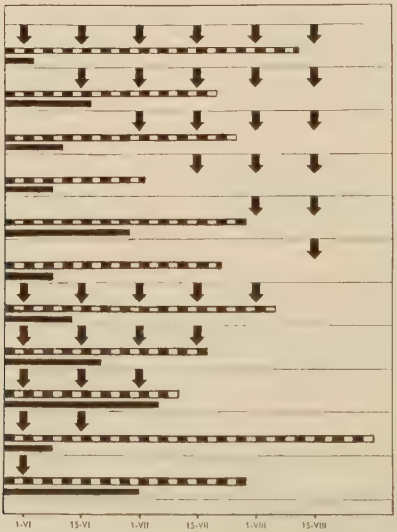

Fig. 27: Results of the curative treatment

Conclusion:

1. A short series of curative sprays carried out after June does not eradicate the sources of infection present, and consequently is a futile measure.
2. The improvements which may be established in the year of treatment are only of an apparent nature, and do not justify the application.
3. A curative method of control is ineffective (the result of the preceding test was confirmed by a similar test conducted in 1952, and in which the treatments were carried out from the emergence stage until the end of the season, in other words from April 11 to August 22).

B. Tests in 1952

Object: These tests were conducted to determine the residual effect of micro wettable sulphur on diseased shoots.

Method: Spraying of the diseased shoots.

Variety: Jonathan.

Concentrations: 0·75 % (tests I and II)
0·5 % (test III)
0·4 % (test IV)

Sprays: April 25 (I), May 30 (II), June 12 (III), July 4 (IV).

Checks:	Test I:	30. 4.	3. 5.	6. 5.	9.5
	Test II:	3. 6.	5. 6.	8. 6.	
	Test III:	16. 6.	19. 6.	21. 6.	24. 6.
	Test IV:	8. 7.	11. 7.		

Results:

Test I: residual effect of 15 days
Test II: residual effect of 8 days
Test III: residual effect of 11 days
Test IV: residual effect of 6 days

In the following table, we have also given details of the total rainfall and the temperatures (average maximum and daily mean) during the period the spray remained effective in each test.

Table of tests

Date	Dosage in %	Rainfall total mm	Rainfall daily max. mm	Temperatures average max. °C	Temperatures daily mean °C	persistence in days
25. 4.	0·75	21·9	6·5	18·5	11·5	15
30. 5.	0·75	25·8	15·4	21·0	15·1	8
12. 6.	0·50	10·8	4·1	20·7	15·5	11
4. 7.	0·40	21·0	13·2	28·7	21·8	6

Conclusion:

1. The effect of a micro wettable sulphur spray may remain persistent for 6 to 15 days depending upon the weather conditions.
2. The above table shows that the efficacy of a treatment is inversely proportional to the intensity of the maximum rainfall. Neither its total quantity nor the temperature appears to play an appreciable part.

Remarks:

1. Other tests carried out in 1953 confirm these conclusions.
2. The addition of adhesives to the spray did not extend the persistence of the preparation.

4. Tests on prophylactic treatment

A. First test:

In view of the complete failure of the curative treatment, it was decided in 1952 to examine in future tests the possibility of preventing incidence of secondary infections known to be responsible for the spread of powdery mildew. Healthy shoots growing close to diseased shoots, and consequently considerably exposed to secondary infections, were sprayed at regular intervals from bud burst until August.

The following two factors were allowed for in the selection of the spraying dates:

1. The number of conidia present in the air (see Fig. 26).
2. The weather conditions.

Records of 1952 test:

1. The test comprised four plots:
   a) Micro wettable sulphur
   b) Solution of soft soap
   c) A mercury preparation
   d) Potassium permanganate

   Each test plot had a check plot in its immediate vicinity, the intention of this being to eliminate any possible errors in the evaluation of the results.
2. 500 healthy branches (on 5 different trees) were treated in each plot. These trees were of the Jonathan variety (13 years old, type II parent stock) which at the time of the tests were severely infected by powdery mildew.
3. Dates of spraying: March 23, April 8, April 16, April 24, May 4, May 15, May 30, June 19, July 4, July 18, August 1.
4. Dosages applied:
   Micro wettable sulphur:
   1 % in first three sprays,
   0·75 % in following four sprays,
   0·5 % in last four sprays.
   Soap: 2 % in each treatment.
   Mercury preparation:
   0·15 % in first three sprays,

0·1 % in following sprays.
Potassium permanganate:
0·2 % in each application.

N. B. With the exception of wettable sulphur, the sprays were discontinued on May 15 because it was found in a check carried out on this particular date that the other three products were ineffective.

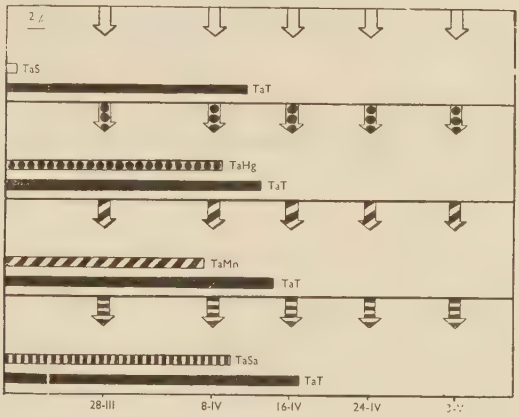

Fig. 28: Results of the prophylactic treatment carried out in 1952

Results:

1st check on May 15, 1952 (counts for 25 branches)

Plots	No. of leaves	No. of spots	Percentage of spots
Micro sulphur (TaS)	1070	11	1
Untreated (TaT)	515	128	24·8
Soap (Ta Sa)	995	225	22·6
Untreated (TaT)	380	114	30·0
Mercury preparation (Ta Hg)	830	182	22·0
Untreated (TaT)	365	96	26·3
Permanganate (Ta Mn)	965	198	20·4
Untreated (TaT)	370	100	27·0

These results are illustrated in Fig. 28.

2nd check on July 19 (25 branches).

This check was carried out only in the plot treated with wettable sulphur (cf. following table).

Check on July 19, 1953

Branch	Total number of leaves	Number of infected leaves	Number of rolled leaves
1	50	1	0
2	70	0	0
3	75	0	0
4	45	1	0
5	60	5	1
6	70	2	0
7	85	7	0
8	65	6	1
9	60	6	3
10	30	2	0
11	30	0	0
12	30	3	0
13	40	2	0
14	45	2	1
15	30	1	0
16	60	2	0
17	50	4	0
18	40	3	0
19	25	0	0
20	50	1	0
21	30	0	0
22	50	5	1
23	50	2	1
24	65	4	0
25	35	1	0
Untreated check	12 40	60 = 4·8 % (TaS) 29·7 % (TaT)	8 = 0·65 % (FS) 16·9 % (FT)

Another count was taken in August. Fig. 29 illustrates the results obtained from the three checks carried out for wettable sulphur.

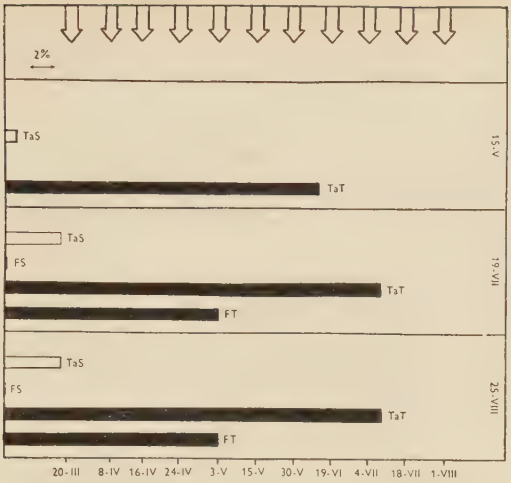

Fig. 29: Prophylactic effect of wettable sulphur as established in the 1952 test

3rd check on May 4, 1953 (25 branches per plot).

This check was carried out to verify the persistence of the effects obtained in 1952 (cf. following table).

Check on May 4, 1953

Plots	No. of buds	Infected buds %	Destroyed buds %
Wettable sulphur	290	3·4	6·8
Untreated	160	37·0	44·3
Soap	320	6·2	50·0
Untreated	160	31·2	43·7
Mercury preparation	300	7·0	49·6
Untreated	110	18·1	46·3
Permanganate	390	5·3	30·8
Untreated	100	11·0	41·0

Conclusions:

a) Wettable sulphur is by far the most effective of the different substances tested. The effect of the other preparations is insignificant (confirmation of 1951 tests).

b) The results of this test demonstrate the possibilities offered by prophylactic controls.

B. Tests conducted in 1953

a) Prophylactic treatments using wettable sulphur

In view of the satisfactory results produced by prophylactic treatments in the 1952 test, a similar test was conducted the following year with the object of:

a) Developing an effective control method

b) Comparing the importance of the different sprays (9 plots).

Allowance was made for the flight of the conidia (see curve for 1953) and the persistence of the product (micro sulphur) at each treatment when selecting the spraying dates.

Dates of spraying:

1st on April 2
2nd on April 15
3rd on April 30
4th on May 12
5th on May 23
6th on June 8
7th on June 18
8th on July 6

Plots	Sprays 1st	2nd	3rd	4th	5th	6th	7th	8th
I	×	×	×	×	×	×	×	×
II		×	×	×	×		×	×
III			×	×	×	×		×
IV				×	×			
V					×			
VI	×					×	×	
VII	×	×				×	×	×
VIII	×	×	×					
IX	×	×	×	×		×	×	×

Dosages:

First three sprays: Micro sulphur at 0·75 %
4th spray Micro sulphur at 0·6 %
Remaining sprays: Micro sulphur at 0·5 %

Results:

A) Check on May 22, 1953

Plots	No. of leaves	No. of spots	Spots expressed in %
I	1 755	87	4·9
II	1 525	58	3·7
III	1 480	60	4·0
IV	1 545	226	14·0
V	1 785	405	22·7
VI	1 450	426	29·0
VII	1 390	345	24·0
VIII	1 415	207	14·6
IX	1 605	90	5·0

These results are reproduced again in Fig. 30. They prove how important the 3rd and 4th sprays are, and also demonstrate the futility of the first two sprays.

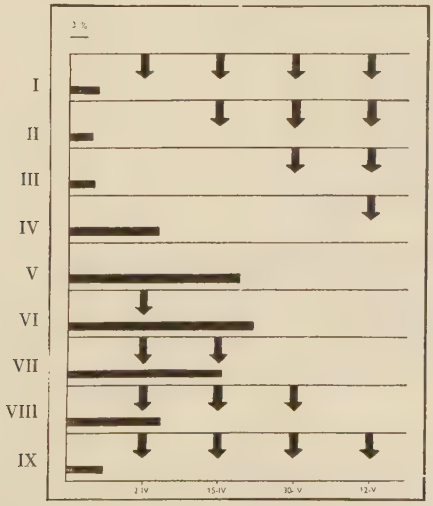

Fig. 30: Prophylactic treatment with wettable sulphur in 1953 (check on May 22)

B) Check on July 30, 1953

Plots	Branches	Branches with rolled leaves %	Branches covered with mycelium %	Healthy branches %
I	216	6·3	0·0	93·7
II	120	8·3	5·0	86·7
III	130	7·7	4·6	87·7
IV	132	25·9	12·1	62·0
V	172	18·6	10·4	71·0
VI	132	25·9	12·1	62·0
VII	112	28·5	15·6	55·9
VIII	116	53·4	10·3	36·3
IX	162	11·1	2·4	86·5

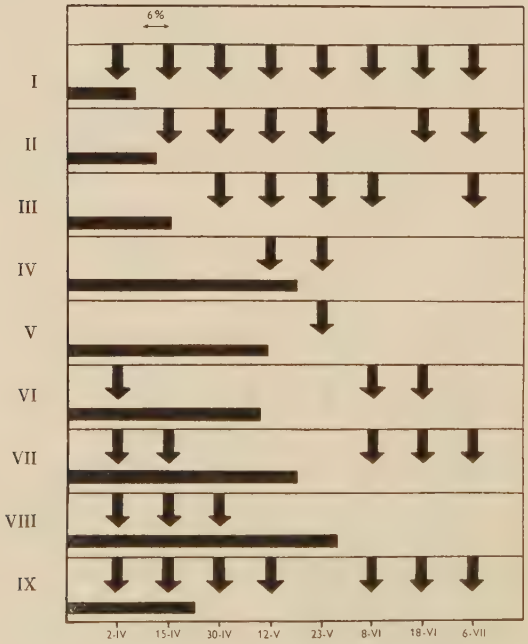

Fig. 31: Prophylactic treatment with wettable sulphur in 1953 (check on July 30)

On studying Figs. 30 and 31, it is found that:

a) The first two sprays need not have been applied.

b) The sprays carried out on April 30 and May 12 were very important (infections on May 1 to 3 and May 16 to 26).

c) The spray applied on May 23 was also effective (infections at end of May), cf. plots I and IX.

d) The spray carried out on June 8 proved to be useful (infections between June 7 and 14), cf. plots I and II.

e) The spray applied on June 18 was also effective (cf. plots II and III).

f) The spray carried out on July 6 was superfluous (cf. plots VI and VII).

C) Check on May 10, 1954

The checks carried out in the test plots in spring 1954 showed that the percentages of infected buds were identical with those registered during the course of the preceding year.

Plots	Infected terminal buds %	Destroyed terminal buds %	Healthy buds %
I	7·4	6·0	86·6
II	7·8	12·1	80·1
III	9·3	11·4	79·3
IV	14·8	32·4	52·8
V	14·4	31·1	54·5
VI	13·1	41·2	45·7
VII	18·3	36·5	45·2
VIII	22·0	42·8	35·2
IX	9·4	15·1	75·5

Conclusions:

1. A prophylactic treatment of healthy branches gives a result of approximately 90 % against powdery mildew.
2. Failure to carry out a treatment during a period when there is a risk of infection, may affect the final result.
3. May is the most critical month for secondary infections. Failure to carry out sprays during this period will result in serious damage being caused.

b) Comparison of several preparations

Object: Comparison of three types of products with wettable sulphur, namely lime-sulphur mixture, colloidal sulphur and preparation 4311 (carbamate mixture).

Dates of spraying and dosages (in %)

Date	Lime-sulphur mixture	Colloidal sulphur	Wettable sulphur	4311
2. 4.	1·5	0·3	0·75	0·2
15. 4.	1·5	0·3	0·75	0·2
30. 4.	1·0	0·2	0·75	0·2
12. 5.	1·0	0·2	0·6	0·2
23. 5.	0·75	0·2	0·5	0·2
8. 6.	0·75	0·2	0·5	0·2
18. 6.	0·75	0·2	0·5	0·2
6. 7.	0·75	0·2	0·5	0·2

Results:

Check carried out on July 30

Plots	No. of branches examined	Branches with mycelium %	Branches with crinkled leaves %	Healthy branches %
Wettable sulphur	216	6·3	0	93·7
4311	228	21·0	8·7	70·3
Colloidal sulphur	228	15·7	3·5	80·8
Lime-sulphur	222	22·5	2·7	74·8

c) Influence of fertilization

According to several authors (e. g. S c h a f f n i t 1930), fertilization plays a part which should not be underestimated with respect to the severity of powdery mildew infections. An excess of nitrogen and a deficiency of potassium in the soil is said to have a favourable effect on the infections.

The following test was carried out in 1953 with the object of examining this hypothesis.

Plots: Four plots each with eight rows of trees (permanent, semi-permanent and temporary) including the Jonathan, Laxton, Cox and Boscoop varieties (36 trees per plot, with 21 Jonathan).

Fertilization: Application of fertilizer by means of a soil injector.

Dosages:

Plot I: 200 parts N + 160 parts P_2O_5 + 400 parts K_2O (one application in spring)

Plot II: 100 parts N + 80 parts P_2O_5 + 200 parts K_2O (spring)
100 parts N + 80 parts P_2O_5 + 200 parts K_2O (summer)

Plot III: 300 parts N + 240 parts P_2O_5 + 600 parts K_2O (one application in spring)

Plot IV: 150 parts N + 120 parts P_2O_5 + 300 parts K_2O (spring)
150 parts N + 120 parts P_2O_5 + 300 parts K_2O (summer)

Sprays: The same treatment was carried out in each plot (wettable sulphur on April 19, April 20, April 30, May 7, May 21, May 28, June 25).

The figures given in the following table represent the average results for four trees.

Influence of fertilization. Results.

Plot	Row	Branches checked	Infected branches	Infected expressed in %
I	1	441	42	9·1
	2	423	39	9·1
II	1	415	21	5·1
	2	461	31	6·7
III	1	417	40	9·6
	2	439	41	8·8
IV	1	419	30	7·2
	2	401	32	8·1
Wettable sulphur plot	2	404	29	7·4
without special fertilization	1	371	21	5·6

Conclusion:

The differences registered are insignificant, and do not permit a conclusion to be drawn as to whether fertilization has any direct and immediate influence on the infections.

d) The advantage of cutting infected branches

The infected branches constitute the principle source of conidia for secondary infections. It is, therefore, of great advantage to cut them down. But the disease cannot be controlled, however, by this practice alone. This will be proved by the following experiment.

At the beginning of 1953, all the diseased shoots, a total of 179 (73, 46 and 60 respectively), were cut off on three comparison trees. Although secondary infections developed on these trees in the course of the year, they were much less serious than on non-pruned trees.

The state of the trees was carefully examined at the beginning of the following year. The following table gives details of the number of newly infected shoots on these trees.

		Infected branches
Pruned trees	1	23
	2	16
	3	13
Non-pruned trees	1	42
	2	54
	3	26

These figures show that the operation produced results which are indisputable but only partially successful. Nevertheless, the removal of diseased branches is strongly commendable as a measure to be carried out supplementary to the application of fungicidal sprays. The following test indicates that the efficacy of chemical sprays can be increased even more by means of this procedure.

Test:

Division of a bush tree plantation into two plots which were evenly treated with wettable sulphur. In plot I, the infected branches were cut off.
The wettable sulphur sprays were applied on April 19, April 22, May 6, May 16, May 28, June 11, June 24, July 10.

Results:

	Leaves checked	Infected leaves %
Plot I	5750	12·9
Plot II	4370	22·2

Conclusions:

It is advisable to remove the infected branches mechanically (reduction of secondary infections and greater efficacy of the sprays).

N. B. Many sources of infection can be eliminated by means of winter pruning. It is, however, commendable to repeat the operation after bud burst because it is difficult to remove all diseased buds in winter.

e) Summary of the test conducted in 1953

1. The good results obtained in 1952 by means of prophylactic controls were confirmed in 1953.
2. The high number of sprays was retained. This number could, however, be reduced when more is known about the dates of the critical infection periods.
3. Wettable sulphur was again superior to the other preparations.
4. Fertilization does not appear to have any influence on the infections.
5. The mechanical removal of infected organs is a most effective practice.

C. *Tests conducted in 1954*

a) Prophylactic control

The results obtained in 1952 and 1953 have given adequate proof of the advantage of carrying out prophylactic controls. The chief purpose of the corresponding tests conducted in 1954 was to obtain a reduction in the number of sprays. Therefore, the sprays were applied only during the natural periods of infection.

The sprays were applied on May 11, May 25, June 4, June 16, July 2, July 23.

Results on June 3, 1954

	Leaves checked	Leaves with spots %
Wettable sulphur plot (0·4 %)	710	4·1
Fungicide A (1 %)	590	8·3
Fungicide B (0·5 %)	955	10·0
Check plot	720	54·1

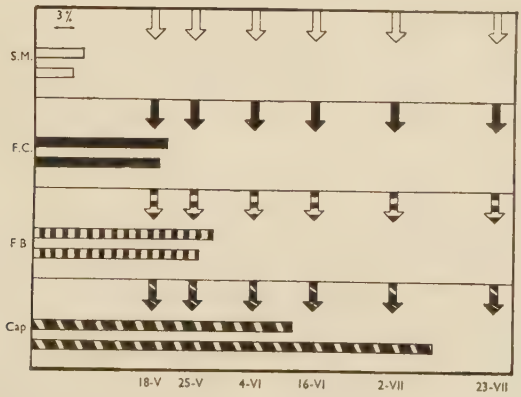

Fig. 32: Comparison of the effect produced by different fungicides (1954 test) (S.M. = Wettable sulphur; F.C. = Fungicide C; F.B. = Fungicide B; Cap. = Captan)

Results on July 30, 1954

	Leaves checked	Crinkled leaves %	Branches with mycelium %
Wettable sulphur	950	1·9	0
Fungicide A	785	20·6	10
Fungicide B	1255	24·3	5
Check plot	357	45·9	21

Results on November 10, 1954

		Branches checked	Healthy branches	Branches with infected terminal buds	Branches with mycelium
Wettable sulphur	I	59	57	2	0
	II	58	57	1	0
Fungicide A	I	51	20	19	12
	II	57	16	25	15
Fungicide B	I	62	40	14	8
	II	76	45	18	13
Check plot	I	55	10	31	14
	II	62	18	29	15

b) Comparison of different preparations

Object: To determine the efficacy of several fungicides in comparison with wettable sulphur.

Preparations tested:

Wettable sulphur at 0·4 %
Fungicide C at 0·2 %
Fungicide B at 0·5 %
Captan (SR 406) at 0·4 %

Dates of spraying: May 18, May 25, June 4, June 16, July 2, July 23, 1954.

Results:

Check carried out on August 10, 1954 (see Fig. 32)

		Leaves checked	Crinkled leaves %	Branches with mycelium %
Wettable sulphur	I	1065	7·5	6·0
Fungicide C	I	730	19·8	20·0
Fungicide B	I	830	26·8	26·6
Captan	I	845	38·1	60·0

Check on November 10, 1954

		Branches checked	Healthy branches %	Branches with mycelium %
Wettable sulphur	I	100	89	11
	II	100	83	17
Fungicide C	I	100	69	31
	II	100	72	28
Fungicide B	I	100	59	41
	II	100	61	39
Captan	I	100	28	72
	II	100	31	69
Check plot	I	100	39	61
	II	100	31	69

c) Comparison of two spray series

Object: to compare the efficacy of sprays based on the natural periods of infection with that of sprays normally carried out against apple scab.

Treatment: Two plots each 1 hectare in area, were sprayed with micro wettable sulphur on the following dates:
Plot I: May 11, May 28, June 15, June 29;
Plot II: April 6, April 16, May 4, May 19, May 31, June 22, June 29, July 6, July 17.

Result on November 10, 1954

		Branches checked	Healthy branches %	Branches with mycelium %
Plot I	a	100	94	6
	b	100	91	9
	c	100	97	3
	d	100	95	5
Plot II	a	100	92	8
	b	100	91	9
	c	100	87	13
	d	100	88	12
Untreated check plot	a	100	58	42
	b	100	40	60
	c	100	44	56
	d	100	49	51

The results tabulated above are illustrated in Fig. 33.

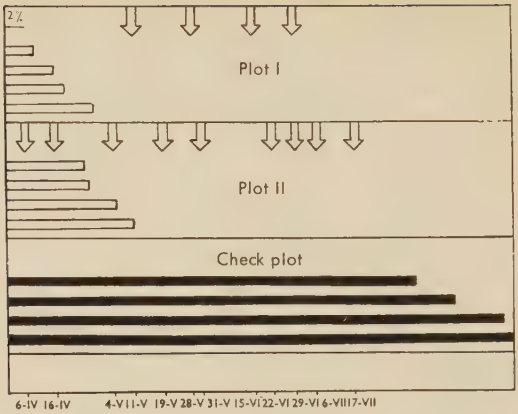

Fig. 33: Efficacy of a spray series carried out at the time of infection

The efficacy of the four treatments carried out specially against powdery mildew is somewhat greater than that of the nine sprays with the same product (against apple scab).

d) Summary of the tests conducted in 1954

1. The prophylactic method gave excellent results.
2. The number of sprays can be reduced considerably when a spraying plan is worked out based on the natural periods of infection.
3. Wettable sulphur is the most effective product.

N. B. Similar tests conducted in two large-scale plantations in our country confirmed these results.

General Summary

This paper has enabled several new aspects to be clarified concerning the biology and control of *Podosphaera leucotricha* (Ell. and Ev.) Salm, which we have summarized below:

1. Biology

a) The overwintering of the fungus in the perfect form (perithecia) is much more frequent than is generally assumed. The part it plays in the spread of the disease can, however, be regarded as insignificant.

b) The mycelium overwinters in the infected buds, and resumes its activities in spring by forming numerous conidia which constitute the chief source of new infections.

c) Secondary infections on the foliage are the starting point for future bud infections. Consequently they play a decisive part in the spread of the disease.

d) It has been established that the most serious infections are generally in May although infections may occur until August.

e) The development of secondary infections depends upon several factors, the most important being the temperature and the presence of young organs. Excessive rainfall hinders the development of infections.

f) The curves plotted for the presence of conidia provide useful indications with respect to the prediction of infections. The peaks of the curves coincide with the critical periods.

2. Control

a) The curative methods of control can be rejected because they do not succeed in killing the mycelium on the diseased organs even when numerous sprays are applied.

b) Excellent results can be obtained by applying prophylactic sprays during the critical periods.

c) The mechanical removal of diseased branches in winter and spring is a measure which is most effective when carried out supplementary to the chemical controls.

d) Among the different fungicides, micro wettable sulphur has so far always produced the best results.

e) The determination of the periods which are favourable for the incidence of secondary infections renders it possible to reduce considerably the number of sprays that have to be applied.

f) A warning service notifying growers when to carry out controls against apple powdery mildew could now be established; the advice it could give to growers would be of great assistance to them in order to carry out an effective control of the disease.

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